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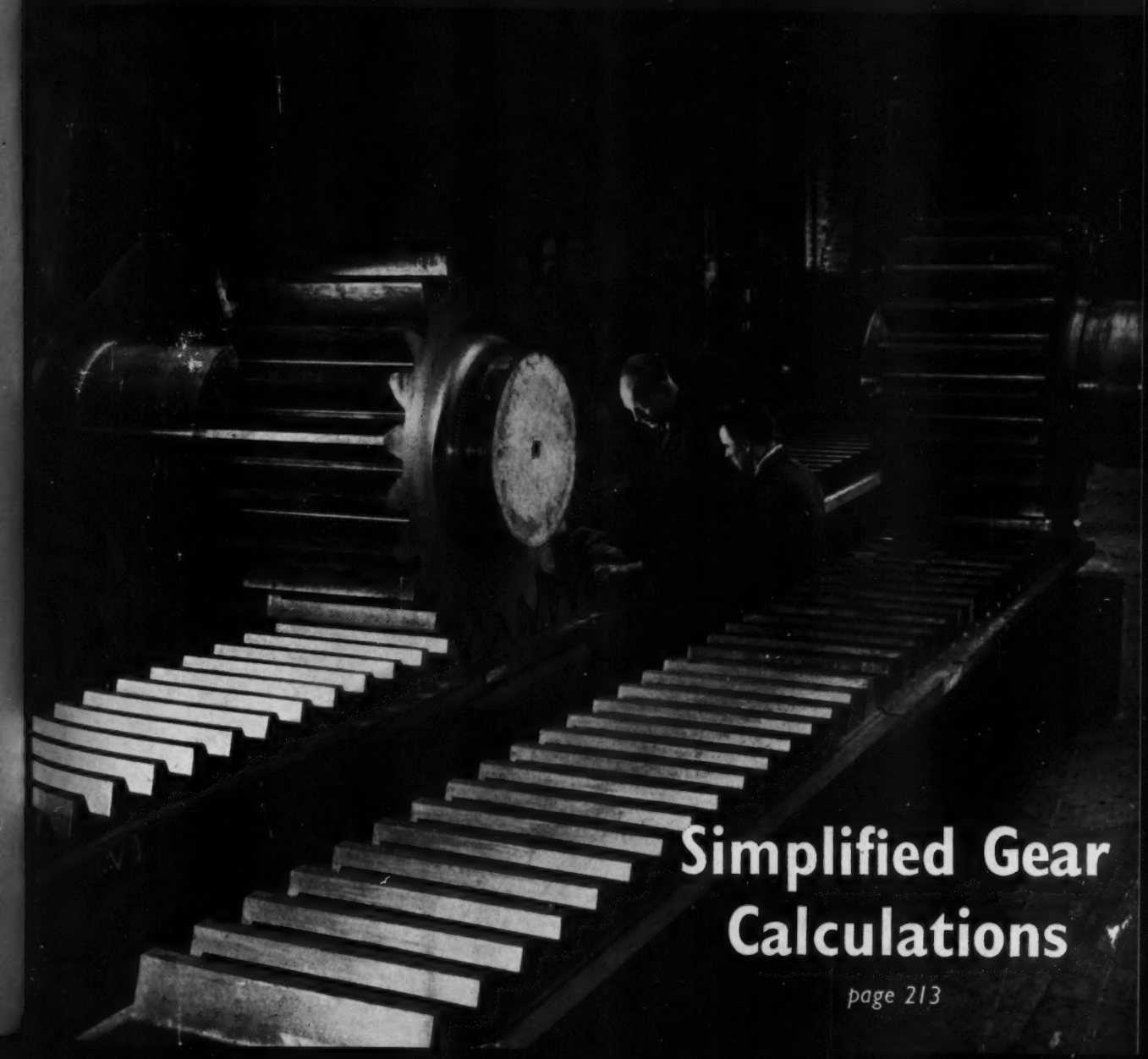

Simplified Gear Calculations

page 213

EMD 2438 for further information

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Engineering Materials and Design

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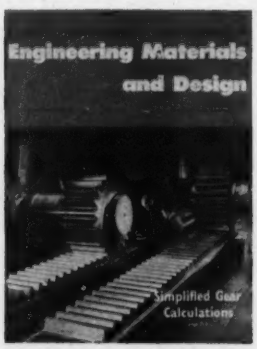

COVER — These heavy-duty racks and pinions for a Bascule bridge form one of a series of subjects photographed by Walter Nurnberg for David Brown Industries Ltd.

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ISSUE AT A GLANCE

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Survey and guide to the types of materials available.
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Design data for spur gear measurement.
By **Wm. A. A. Witham, A.M.I.E.D.,** and **A. G. Beaveridge, Grad.I.Mech.E.**

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Résumés

SIMPLIFICATION DES CALCULS D'ENGRENAGES

W. A. A. Witham et A. G. Beaveridge page 213

Cet article offre des renseignements essentiels pour la mesure des engrenages droits et décrit des méthodes de calcul simplifiées que peut utiliser l'ingénieur dessinateur appelé, parfois, à entreprendre ce genre de travail.

MATERIAUX POUR AIMANTS PERMANENTS

R. H. Warring page 208

Dans cette étude, l'auteur passe en revue divers matériaux utilisés dans la fabrication des aimants permanents : alliages d'acier, alliages durcis par précipitation et ferrites. Il examine leurs mérites respectifs et donne leurs caractéristiques dans des tableaux complets faciles à consulter.

PRODUCTION DE PIECES DE FONTE HAUTEMENT RESISTANTES

E. G. Donaldson page 221

L'auteur étudie la technique employée dans la production de pièces de fonte hautement résistantes et indique des moyens pratiques permettant de fabriquer ces pièces de fonte à meilleur marché ou de façon à en exploiter les propriétés plus efficacement.

LOCALISATION DES POINTS DE FRICTION SUR LES ARBRES

D. Denman page 218

L'article examine l'emploi systématique d'anneaux coniques pour localiser les points de friction sur les arbres. Il décrit un certain nombre d'applications dans lesquelles les anneaux ont donné de bons résultats et suggère d'autres applications possibles.

SOUDURE A HYDROGENE ATOMIQUE

Eric N. Simons page 226

L'auteur décrit les avantages et les inconvénients de ce procédé et le compare à la brasure. Parmi les applications, il cite la réparation des outils, le surfaçage des lames d'arbres d'alésage, et des lames de machines pour le travail du bois, la récupération et la réfection d'outils, et autres usages.

LES MATERIAUX MODERNES POUR BANDES TRANSPORTEUSES

J. A. Hardman page 231

L'article discute les rapports entre les propriétés physiques et la structure moléculaire des matériaux pour courroies et bandes transporteuses ; il définit les qualités nécessaires des courroies par rapport à leur travail. Ces qualités sont associées aux propriétés du caoutchouc naturel. Les exemples portent sur le chloroprène, les caoutchoucs acryliques, le p.v.c. (chlorure de polyvinyle) et les caoutchoucs aux silicones.

Kurzreferate

VEREINFACHTE BERECHNUNG VON ZAHNRÄDERN

W. A. A. Witham und A. G. Beaveridge seite 213

Der Artikel bringt grundsätzliche Konstruktionsdaten über die Dimensionen von Stirnrädern und stellt dem Konstrukteur, der mitunter Arbeiten dieser Art zu erledigen hat, vereinfachte Berechnungsmethoden zur Verfügung.

BAUSTOFFE FÜR DAUERMAGNETEN

R. H. Warring seite 208

Eine Besprechung der verschiedenen Arten der für Dauermagneten benützten Baustoffe, d.h. Legierungsstähle, Vergütungslegierungen, und Ferrite, und ihrer Vorteile. Die den Artikel begleitenden Tafeln geben eine gute Übersicht der Kenndaten.

DIE KONSTRUKTION VON HOCHLEISTUNGS-EISENGUSSFORMSTÜCKEN

E. G. Donaldson seite 221

Der Verfasser bespricht die bei der Konstruktion von Hochleistungs-Eisengussformstücken verwendete Methode und zeigt Möglichkeiten an, mittels welcher diese Gussstücke so entworfen werden können, dass sich ihre Herstellung verbilligt, oder dass ihre Eigenschaften besser ausgenützt werden können.

REIBUNGSSCHLÜSSIGER ANBAU AN WELLEN

D. Denman seite 218

Der Artikel befasst sich mit dem weitgehenden Einsatz von Friktions-Kegelbüchsen zum Anbau an Wellen und beschreibt eine Vielzahl von Anwendungsmöglichkeiten, bei welchen sich diese bewährt haben ; weitere Möglichkeiten werden vorgeschlagen und diskutiert.

ARCATOMSCHWEISSUNG

Eric N. Simons seite 226

Der Verfasser bespricht die Vor- und Nachteile dieses Verfahrens und vergleicht es mit der Hartlötung. Einige der besprochenen Anwendungsgebiete sind : die Reparatur von Werkzeugen. die Bestückung von Bohrstangenschneiden, die Bestückung von Messern von Holzbearbeitungsmaschinen, Formschneiden, Reparaturwerkzeuge und andere Zwecke.

MODERNE BAUSTOFFE FÜR FÖRDERBÄNDER

J. A. Hardman seite 231

Der Verfasser bespricht die Zusammenhänge zwischen den physikalischen Eigenschaften und der molekulären Struktur von Materialien für Förderbänder und die Anforderungen des Bandmaterials mit Hinsicht auf seinen Dienst. Diese werden mit den Eigenschaften von Naturgummi verglichen. Die besprochenen Beispiele umfassen Chloroprenkautschuk, Akrylgummi, PVC und Silikongummi.

Резюме

УПРОЩЕННЫЙ РАСЧЕТ ЗУЪЧАТЫХ КОЛЕС

В. А. А. Уитэм и А. Г. Биверидж стр. 213

В статье приводятся важнейшие конструкционные данные, касающиеся измерений зубчатых колес, и объясняются упрощенные способы их расчета для сведения конструкторов, которые иногда могут встретиться с подобной задачей.

МАТЕРИАЛЫ ДЛЯ ПОСТОЯННЫХ МАГНИТОВ

Р. Х. Уорринг стр. 208

Обзор различных материалов для постоянных магнитов : стальных сплавов, пульверизационных твердых сплавов, ферро-сплавов- и анализ их сравнительных качеств. Все данные сведены в удобочитаемые подробные таблицы.

КОНСТРУКЦИЯ ТЯЖЕЛЫХ ЧУГУННЫХ ОТЛИВОК

Э. Г. Доналдсон стр. 221

Автор описывает технологию производства тяжелых чугунных отливок и описывает практические методы снижения себестоимости отливок и повышения их качества.

ФРИКЦИОННЫЕ НАСАДКИ НА ВАЛЫ

Д. Денман стр. 218

Констатируется широкое применение конических насадок на валы ; описываются различные виды их использования, доказавшие свою ценность ; и предлагаются новые возможные способы их применения.

АТОМНО-ВОДОРОДНАЯ СВАРКА

Эрик Н. Саймонс стр. 226

Автор обсуждает преимущества и недостатки этого процесса, сравнивая его с пайкой твердым припоем. В частности процесс применяется для починки инструментов, правки режущих поверхностей бор-штанги, обточки деревообрабатывающих резцов, формовки резцов, капитального ремонта инструментов и т.д.

НОВЫЕ МАТЕРИАЛЫ ДЛЯ КОНВЕЙЕРНЫХ ЛЕНТ

Дже. А. Хардман стр. 231

Анализируется взаимосвязь между физическими свойствами и молекулярной структурой ленточных материалов и определяется зависимость материала ленты от ее предназначения. Полученные формулы сравниваются со свойствами резины. Разбираются примеры : хлоропрен, акриловая]резина, поливинилхлорид и кремниевая резина.

MATERIALS IN THE NEWS

Monthly Digest of Materials and Design News from Home and Abroad

Attacking Noise with Lead

THE LEAD INDUSTRIES ASSOCIATION in the U.S.A. have recently initiated a programme of investigation to determine the engineering data necessary for the increased use of lead-asbestos pads for confining vibration in machinery and buildings. Lead as a metal is usually limited to applications where its corrosion resistance or weight are the primary factors. Its use in lead acid batteries, not only for the active plates but also as a conductor of current, is due partly to its resistance to corrosion but also because lead is one of the cheapest conductors of electricity, when examined on an amps-per-£1 basis.

Lead has already been used as a sound deadener and to prevent drumming on the Block and Anderson typewriter, being used in this application purely to add mass on a light metal pressing. The use of a lead-asbestos composition is being studied because this material has an inherent vibration attenuating property.

The use of lead pads for diminishing vibration has been known in this country for many years and a material known as Mellopad (Mellowes & Co. Ltd.) has been used extensively for incorporating in machinery foundations. This consists of an outer lead alloy cover filled with two layers of fibreboard, each being separated by a lead alloy strip. This material is not primarily a noise absorber but, by preventing the transmission of vibration from machines like drop stamps, will obviously help to reduce the noise in adjacent areas.

In the development of lead for sound attenuation the U.K. appear to be somewhat behind the Americans and the French, who are devoting more effort to this subject, apart from the building field where British architects have sometimes employed plywood-lead sandwich panels, such as those made by Venesta Ltd. The Lead Development Association is trying at the present time to interest manufacturers in the U.K. to specialise in the new techniques and materials now under development in the U.S.A.

Tungsten for High Temperatures

TUNGSTEN IS ONE OF THE FEW METALS that possess structural strength at temperatures above 2,000 deg. C. Its extremely high melting point (3,140 deg. C.), hardness and corrosion resistance make it a desirable material for high-temperature equipment. However, until lately, the high-temperature properties of tungsten could not be effectively utilised. Its brittleness and hardness prevented it from being machined by conventional methods while its weight restricted its uses in aeronautical equipment. For these reasons, efforts were made to develop a practical method for depositing tungsten coatings.

High-purity tungsten can now be easily plated on metal surfaces by using a vapour deposition process which the National Bureau of Standards has developed for the U.S. Navy. The method involves reducing gaseous tungsten hexafluoride with hydrogen by passing it over the heated object to be plated. At temperatures above 300 deg. C., tungsten is deposited on the hot surface, and the only other reaction product—hydrogen fluoride—passes out with the excess of hydrogen.

By this method, it is possible to coat numerous simple and complex surfaces such as rocket and missile nozzles and jet engine parts. The technique also lends itself to the fabrication of tungsten articles, and may be the only way that complicated shapes of tungsten can be formed. Simple tungsten shapes for use in vacuum tubes have already been fabricated.

A new high-temperature alloy developed by Stanford Research Institute metallurgists is said to be performing successfully at temperatures up to 950 deg. C. in jet engines. The alloy, being used for turbine nozzle vanes in the Pratt & Whitney J-57 engine that powers the 707 and DC-8, was developed under a research contract for the Tungsten Institute. Known as WI-52, the alloy contains 13 per cent tungsten and supplants the X-40 alloy, which has been in use since 1941 with an operating peak of 870 deg. C. WI-52 is said also to give more thrust per pound of engine, decreases fuel consumption and lengthens engine life. Additionally, protective coatings of chromium and aluminium have been developed to offset the oxidation which occurs at the 950 deg. C. range. Other applications of the alloy are possible, although these have not been explored by S.R.I. Some possible uses might be in hot tools for forming, furnace components and brazing fixtures.

Plastics for Railway Carriage Doors

RAILWAY CARRIAGE DOORS, traditionally made of steel and timber, have been the subject of much experiment over the past few years. The steel product is comparatively heavy, costly in labour, and very susceptible to corrosion. Against this, it is very robust, not easy to damage, and compares very favourably in total initial cost with doors made from other materials.

If they could be made lighter, assembly costs would probably be reduced, and running costs would certainly be lowered. A saving of only 14 lb. in the weight of each door means that a normal-length suburban train has 1 ton less to carry. Probably more important, substantial savings are possible if a new design could be made which would require less maintenance, especially if it was also more resistant to damage and distortion.

Doors using light alloys instead of steel were produced which weighed a little less, and, although somewhat more expensive to make, did very well in trials. They are very resistant to corrosion, and strong. In addition, they have been found to last rather longer than steel doors, so that they compare well economically. These aluminium doors are now in normal service on new railway stock, notably on B.R. southern region main line routes. An obvious advantage they have over the conventional product is in the use of plastics-faced interior panels, replacing the older leathercloth-covered plywood panels.

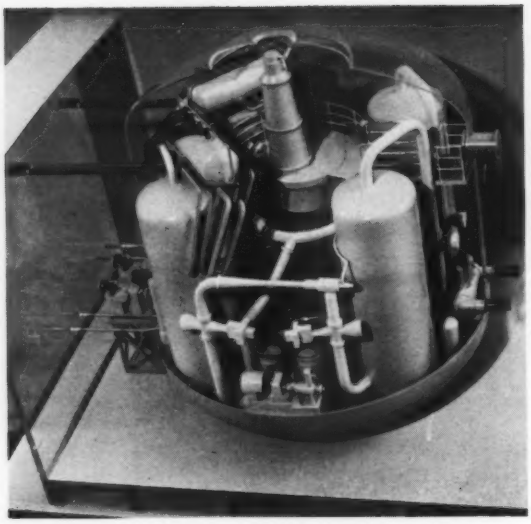
Trials were started several years ago on designs based on reinforced plastics. After preliminary investigations had proved favourable, service tests were carried out on doors made from a structural laminate of Bakelite polyester resin reinforced with glass fibre.

Although the materials for the reinforced plastics door cost more, it takes less labour to produce than the conventional steel door. It is now known that, for at least some types of door, the finished reinforced plastics version costs less to produce than an aluminium one. In addition the plastics product cannot corrode and is extremely resistant to distortion and impact damage. Compared with other types, it is very light in weight, and being somewhat more resilient than metal doors, it regains its shape very quickly after severe loadings, without needing periodic adjustment.

Now, they are being put into normal service on suburban lines. These doors, known as the S.R. type, are in large-quantity production at the S.R. Carriage and Wagon Works, Eastleigh, using a fire-retardant grade of Bakelite resin. Being unaffected by weathering the doors do not need surface protection, and painting is only carried out so that the colour and surface match the surrounding metal parts of the carriage. The surface layers of resin are pigmented green, so that if scratches do remove the paint the marks are not so apparent.

PICTURE NEWS

IN THE WORLD OF MATERIALS & DESIGN



MARINE REACTOR

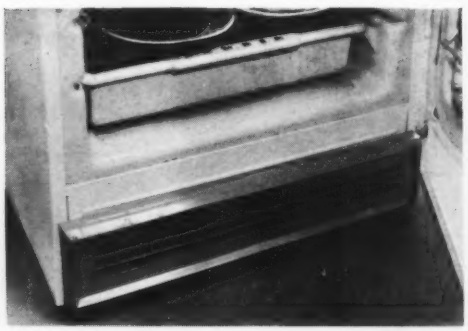
This is a model of the steam-cooled heavy water moderated reactor, with associated plant, designed by Vickers Nuclear Engineering Ltd. for the propulsion of merchant ships. Recent successes of the U.S. submarine "Nautilus" has renewed interest in the future of nuclear powered ships.

RUDDER BEARINGS

Bearings for the 42-ton rudder of the liner "Canberra," which was due to be launched on March 16, are made from Tufnol laminated plastics strip. The material, also used outboard for intermediate steady bearings (shown here) supporting the propeller shafts, is claimed to have low water absorption, consistent quality and easy machinability.

DUAL PURPOSE ▼

The Rigidex high-density polythene kick plate fitted to the new P.60 Lec refrigerator performs the double function of withstanding hard knocks and kicks and of allowing free circulation of air beneath the unit, thereby helping the motor compressor to operate at maximum efficiency.



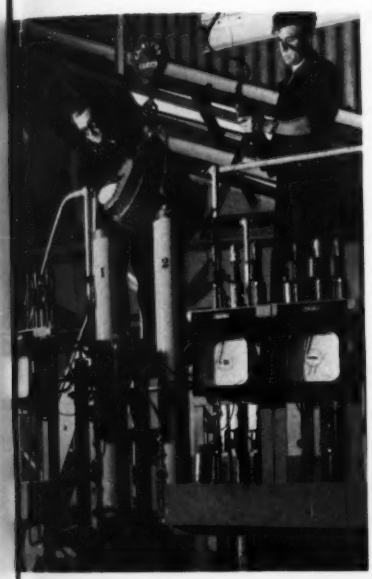
PRODUCING RESISTORS ▼

Since the creation of a link between the Plessey Co. Ltd. and Elettronica Metal Lux of Milan, a new production unit has been established at the Plessey capacitors and resistors division at Swindon. Here is part of the production process in which Metallux resistors are axially ground to the correct resistance value.

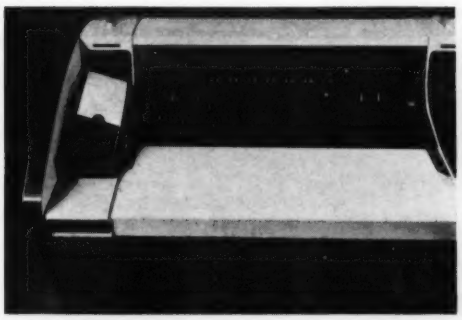
BOUND FOR U.S.A. ◀

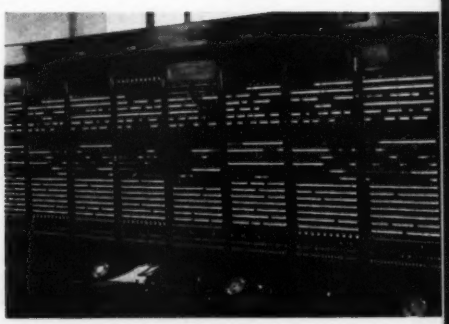
The first four of thirty-five outdoor oil circuit breakers are given a final check at the English Electric Stafford works before being shipped to the Los Angeles Department of Water and Power. The 34.5 kV single-tank breakers have a current rating of 1,200 amps and a breaking capacity of 1,000 MVA.

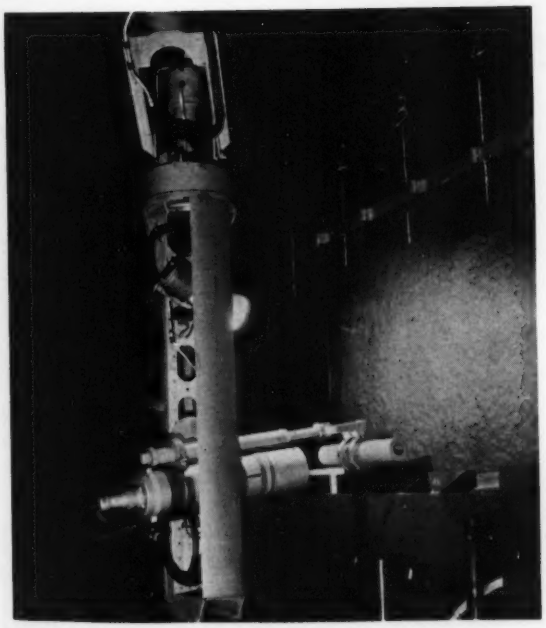
BRITISH CONVERTIBLE
Just making its debut in Geneva is the new Triumph Herald convertible, the open air version of the already established saloon and coupe models. It has all-round independent suspension, has a twin carburettor version of the Herald 948 c.c. engine developing 50½ b.h.p. at 6,000 r.p.m.



MOULDING ROLLERS ◀
Prepared polyurethane liquid is seen here at an Avon factory being poured into a mould for making printing rollers. Final chemical reaction is achieved by heating to a temperature in excess of 120 deg. C. for a specified period of time. The heating completes the reaction and solidifies the liquid, allowing the cast rollers to be withdrawn from the mould.







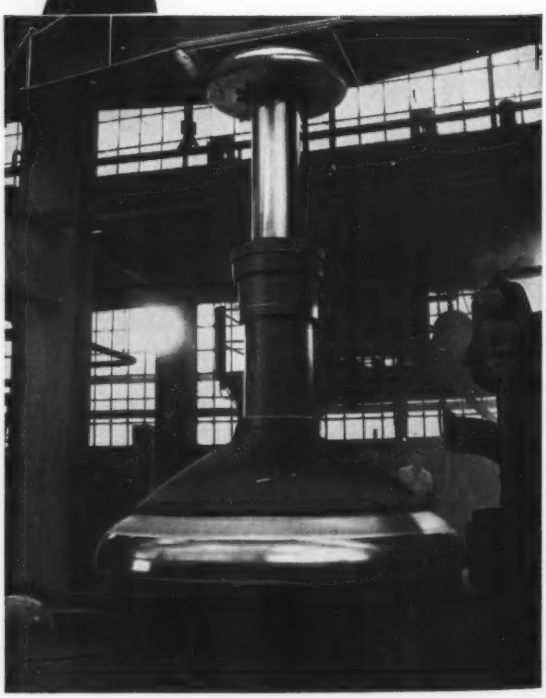
G.P.O. AUTOMATION
These two pictures show the trend of modernisation in the G.P.O. Right is a typical manual trunk position showing cord and multiple arrangements, at Birmingham exchange. Left is one of the latest automatic trunk position for subscriber trunk dialling at Thanet.

ROBOT GRAB
This robot hand, complete with a television "eye," was designed for removing spent radioactive cartridges from inside atomic piles. Operation of the grab, camera and light which are mounted on the boom, is controlled from a derrick head. Built to U.K.A.E.A. designs by Sir W. G. Armstrong Whitworth Aircraft Ltd.

E.M.D. 2512 for further information

Over a Ton of Aluminium Alloy spun to 10 ft. i/d x $1\frac{5}{8}$″

One of a number produced for pressure vessels to hold liquid air, this 10 ft. aluminium end was spun by Harveys on the Rotarpress. The 12 ft. flat discs needed for spinning these ends, which are believed to be the largest spun aluminium ends produced in this country, were formed by butt-welding two plates of aluminium alloy together.



The Rotarpress is one of the large-capacity units in Harveys Heavy Fabrication Department. It produces ends up to 15 ft. diameter and is adaptable over a wide range of knuckle radii and depths.

The contours of semi-ellipsoidal ends produced by the spinning process enable plate thickness to be reduced, and in most cases tool costs are eliminated. Enquiries are invited for ends only or for complete

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HH/7

Computer to Make Computers

A GIANT ELECTRONIC COMPUTER is being used by the Datamatic division of Minneapolis-Honeywell to produce a "second generation" all-transistorised data-processing system in record time. The new computer, the Honeywell 800, will be produced at a rate that would be impossible if a "parent" computer were not available to help in production. It is estimated that a minimum of six months in the engineering and design departments alone will be saved from the time of the original conception of the system's design through the "testing out" of the first prototypes.

Approximately 10,000 drawings of electrical circuits that would otherwise have been required have been eliminated, and replaced by lists of tables and symbols recorded on magnetic tape. This partial elimination of traditional blueprints and the reduction of tedious drafting jobs is symbolic of the new design method being employed, but with it must be coupled the advantages of speed, accuracy and agility.

"Self-propagation" is how Minneapolis-Honeywell describes the use of a computer to produce another computer. This picture illustrates the contrast between the magnetic tape that is used and some thousands of drawings of electrical circuits which would otherwise be needed.

Brazing Uranium

ATTEMPTS TO JOIN reactive metals such as uranium and thorium to other metals by means of oxy-gas brazing have proved to be unsatisfactory, as such metals are easily contaminated by the oxygen, nitrogen, carbon monoxide, carbon dioxide and water vapour—the usual exhaust gases of an oxy-gas torch.

In view of this, a member of the metallurgy division at the Atomic Weapons Research Establishment, Aldermaston, invented a brazing torch which uses an intense electric arc to heat a stream of inert gas—mainly argon—to very high temperatures. The torch is so designed that it produces a needle-like jet of intensely hot gas which blankets the surface under treatment and protects it from contaminant gases. The temperature of the "flame" can be controlled by limiting the power input to the torch.

Other work for which the torch can easily be adapted includes local heat treatment and stress relieving, softening metals for bending and, in short, any process for which an oxygen gas torch would normally be used.

The torch was originally designed for use in an argon-atmosphere glove-box but could equally well be used for work on such metals as zirconium, titanium and beryllium.

Beryllium Plant Opens

BERYLLIUM COMPONENTS for the latest type of nuclear reactors will be produced at a new Coventry plant, described as the first large-scale facility in Britain for machining the metal. It has been built for Sir W. G. Armstrong Whitworth Aircraft Ltd. The light metal, available in small quantities in the past because of extraction and refining difficulties, has come into prominence recently because of its nuclear power applications. It is to be used as a canning material, for example, for fuel elements in the new advanced gas-cooled reactor at Windscale. The metal will operate at temperatures higher than those in the Calder Hall reactor which has been running successfully for nearly four years.

Much interest was shown in beryllium at the Engineering Materials and Design Exhibition where the U.K.A.E.A. stand was exclusively devoted to the metal. The paper by Dr. A. J. Martin and read at the allied conference was also in demand, showing the growing practical interest in beryllium.

It has, however, disadvantages to general use in industry. It is quite expensive and is very brittle. Also, although the metal itself is not dangerous (it is in no sense radioactive), there are hazards associated with beryllium when it is in the form of fine dust.

Armstrong Whitworth Aircraft's new factory contains pressure "shells" which are supplied with filtered and heated air which is changed every three minutes.

All machining processes are carried out inside completely enclosed machines, provided with their own high speed extraction systems, and any air leaving these contact areas passes through an elaborate system of filters and is purified before being allowed to escape to atmosphere up a 120 ft.-high chimney.

The whole building has been designed to reduce fire risks upsetting health-protection precautions. All furniture, apparatus and equipment is made of steel, and the building fabric is of fire-resistant materials. To ensure complete health protection, elaborate safeguards have been taken. These include the issue of special clothing and a self-contained laundry, together with showerbaths for the personnel.

If beryllium proves to be satisfactory in the a.g.c.r. at Windscale, and seems to be an economic proposition, there is no doubt that there will be a great increase in the demand for machining this metal for components in nuclear power engineering.

Not all of the capacity of the new plant will be taken up in the production of beryllium components for nuclear power. Already, other applications are being found for beryllium in small quantities in guided weapons and other space-age activities, such as the manufacture of gyros.

The Bassett Process

WHEN AN ALLOY is conventionally heat-treated to any degree of hardness or tensile strength it becomes brittle, and under stress and strain may lose its ability to withstand plastic deformation without fracturing. This loss of ductility in the high tensile ranges necessarily limits the usefulness of an alloy, for in many instances ultimate tensile strength is sacrificed to maintain a usable and workable combination of characteristics.

With the Bassett process of heat treatment, it is claimed that ductility actually increases along with the tensile strength, even in the ultra-high tensile ranges. Along with increased ductility it is said that improvements can also be obtained in yield strength, elongation, reduction of area, fatigue life, impact strength, notch sensitivity and resistance to corrosion. Size effect is also greatly improved making it possible to through-harden larger sections thereby maintaining tensile strength and ductility for any thickness of the treated part.

Among the many metals processed by the Research Development Corp. of America, the following have thus far shown excellent results: precipitation hardening austenitic and semi-austenitic stainless steels, martensitic alloy and stainless steels, alpha-beta martensitic titanium alloys, carbon steels, hot worked die steels, high speed and tool steels.

Because of the increased strength, hardness, toughness and ductility, the mass or pound weight can be reduced from 10-60 per cent depending on the alloy, its use and the combination of physical properties desired. In spacecraft this aspect is very important, and is no less important in other industrial applications where it has a direct bearing on costs.

To quote a specific example, an alloy steel which, with standard heat treatment, gives an ultimate of 270,000-287,000 p.s.i., a yield of 250,000-270,000 p.s.i. and an elongation of 9-11 per cent with a reduction of area of 35-38 per cent, can be treated by the Bassett process to give an ultimate of 361,000 p.s.i., a yield of 361,000 p.s.i. and an elongation of 6 per cent with a reduction of area equal to 31.6 per cent.

INTRODUCING THE NEW D.P.60 MECHANICAL LUBRICATOR

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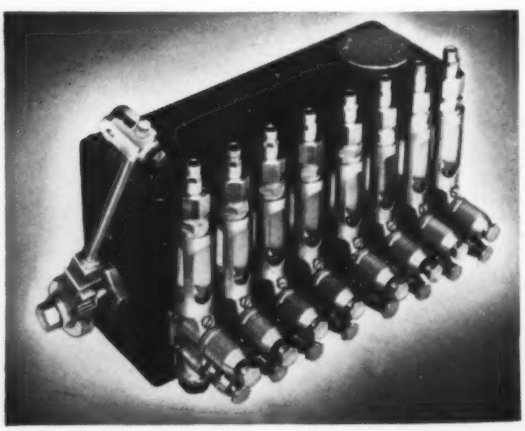

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EM

Special Train for Poland

BELGIUM RECENTLY SUPPLIED the Polish Railways with four mobile high-voltage traction substations each capable of a d.c. output of 4,400 kW.

For this Poland sent a train of twelve 20-metre flat trucks to the Belgian manufacturer (A.C.E.C. at Charleroi) who was to fit them with the complete equipment and the appropriate bodywork. The order was for four complete substations each on three trucks of which two carry the two transformer-rectifier units with their control gear and the third the line breakers, the control panel, the line testing equipment and the harmonic filters. These entirely automatic substations are designed to operate without supervision and can if required be remotely controlled. They are fed from 30kV a.c. power lines and feed d.c. current at 3,300 volts to the Polish railway network.

In each of the first two trucks of a substation are the H.V. 30 kV/630A isolating switches, a 2,465kVA three/six phase transformer with H.V. tappings of ± 2.5-5 and 7.5 per cent. two parallel 1,100kV forced air cooled rectifiers with twin triple anode elements, together with their pumping sets, producing the 3,300 volt d.c. current, a high speed circuit-breaker in the cathode circuit, a cathode reactance coil and the anode surge diverters.

The third truck contains the d.c. 3,300-volt control gear consisting of 6 feeder equipments (one is a reserve), 18 single-pole 3,600V/2,000A isolating switches, an automatic line testing equipment, a resonant shunt harmonic filter, a 110-volt battery for closing the cathode circuit-breakers and finally the operating and control switchboard made up of two separate panels for the rectifiers of trucks 1 and 2, a panel for the auxiliary services and 6 panels for the feeders.

With this equipment these mobile substations can do a duty comparable with that of the well-known fixed substations in a space limited to the size of three railway trucks.

THE MAY ISSUE...

of Engineering Materials and Design will include the following main features:

Design of Anti-vibration Mountings
Advances in rubber technology and vibration insulation.

Hydraulic Infinitely Variable Speed Transmissions
Survey of fluid-operated stepless transmission units.

Sprayed Ceramic Coatings
Techniques for combining thermal and abrasion resistance of alumina.

Surface Active Agents and the Designer
How properties of water can affect other materials in design.

Special Purpose Alloys
Electrical and magnetic properties of nickel alloys.

Nuclear News

A NEW LOW-PRICED DESIGN of nuclear research reactor is to be marketed by G.E.C. Ltd. This reactor, called the Consort, is one of an inherently safe type, using ordinary water as both moderator and coolant. It has been designed jointly by the G.E.C.-Simon Carves Atomic Energy Group and the nuclear power group at the Imperial College of Science and Technology, London. Consort, the only completely British designed research reactor in the 10kW range, is intended to meet the specialised research and training needs of universities and colleges.

It was designed with a view to combining some of the principal advantages of the two well-known types of water-moderated research reactors, the "swimming pool" type and the "enclosed tank" type. The core is located only 10 ft. below the surface of the water moderator in an open-topped tank, but additional shielding is provided in the form of movable concrete-filled trolleys which cover the top of the tank while the reactor is in operation. It has been possible to incorporate an experimental "bare face," protected by portable shielding blocks, closely adjacent to the reactor core, a most important facility for research and training purposes. When the reactor is shut down, the shielding trolleys can be withdrawn and manipulation of the fuel elements can then be carried out beneath the water, under direct observation by the operator using simple manual techniques. In addition, the whole design is based on the use of a well-proved type of enriched uranium alloy fuel element which is readily obtainable from the U.K.A.E.A. as a standard production item.

Across the Atlantic, a further stage of success is announced for the world's first atom-powered merchant ship, the *Savannah*: the nuclear power core for the vessel has achieved a sustained chain reaction at the Babcock and Wilcox laboratory at Lynchburg, Va. It is believed to be the first propulsion reactor power core known to achieve criticality before installation.

The test is said to have confirmed nuclear design and engineering calculations, and provided first-hand experience for the safe installation of the core aboard the *Savannah*.

Weighing more than 15 tons, the core is made up of thirty-two fuel elements containing 4.2 and 4.6 per cent enriched uranium, twenty-one control rods, and internal "hardware." It contains the heaviest known quantity of uranium ever used in a commercial critical experiment laboratory test.

The core was tested in a tank 9 ft. diameter and 17 ft. high, filled with more than 10,000 gallons of de-ionised, or purified, water. Each fuel element weighs about 800 lb. and contains 164 stainless steel rods loaded with uranium pellets. Each of the twenty-one control rods, which are used to regulate the reactivity and to compensate for fuel consumption within the reactor, weighs 225 lbs.

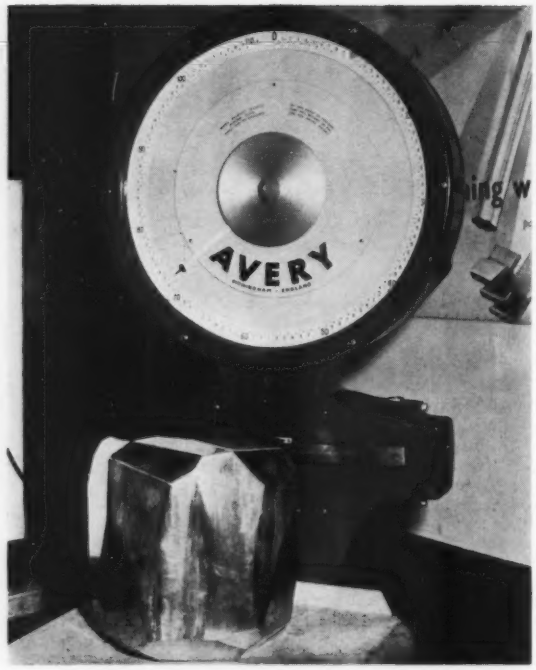
A report has now been issued (and presented at the Symposium on Nuclear-Propelled Merchant Ships held recently in Hamburg) on the study made by the U.K.A.E.A. of a number of nuclear reactor systems for marine propulsion. As with land-based nuclear plants the high capital cost is expected to outweigh any advantages in low operating costs, at least as far as a 65,000 dwt/tanker is concerned. It is possible that a higher powered high-speed passenger vessel would present a more favourable economic picture. So far no one system appears to be markedly superior but it is clear that efforts must now be concentrated on a simplification of reactor design and engineering in order so that a lower capital cost may be achieved. This requirement has led to the conclusion that the two gas-cooled reactors discussed in detail are not worthy of further consideration so far as the 65,000 dwt. tanker is concerned.

Borated Graphite

IT HAS BEEN REVEALED that for the first time special borated graphite blocks were used by the U.K. Atomic Energy Authority in the assembly of the shield which surrounds the reactor vessel at their experimental station at Dounreay. The blocks were made and machined by the Morgan Crucible Co. Ltd. at their works near Worcester. This factory is not engaged in the production of nuclear pure material and was therefore chosen as one suitable for handling large quantities of boron compounds.

The purpose of the borated graphite is to slow down fast neutrons and then absorb them in the shortest possible distance, thus providing a safety screen.

Most of the borated graphite contained 0.3 per cent boron, but some contained 5 per cent—in both cases very uniformly distributed throughout the graphite. The blocks themselves were machined to 500 different patterns. Some of the patterns were so intricate that wooden dummies had first to be made to ensure that it was practicable to machine them in graphite. As a final check, the layers of finished graphite blocks were assembled into their complicated form of eccentric circles. The blocks, painted with distinguishing coloured bands to avoid any risk of confusion with nuclear pure material, were then packed into cartons for transport to Dounreay.



The magnesium block was weighed on the final day of the exhibition after the "Emdee" competition was closed.

Problem of Mass

IF YOU WERE ONE of the 2,206 people who entered the weight-guessing competition on the E.M.D. stand at the Earls Court exhibition during February, here is the answer that has won six people a prize. The "Emdee" pineapple was, in fact, a block of solid magnesium that had been machined to shape but was otherwise untreated except for a brisk polish.

As there was no indication of the identity of the metal, and visitors were not permitted to handle it, estimates of its weight were accordingly varied—and wild! They ranged from 5 oz. to 1 ton.

Its actual weight was 72 lb. 6 oz. The nearest correct entry was made by Mr. E. M. Cowburn, of Saffron Walden (72 lb. 4 oz.). It has been decided, however, also to award prizes to five other entrants who were within a few ounces of the correct weight; these are Mr. A. D. Riden of Liverpool, Mr. Derek Taylor of Ashtead, Surrey, Mr. C. F. Way of New Malden, Mr. P. H. Collinson of London, and Mr. R. Sagane of London. Each of these will be each receiving an engraved Otis King calculator and a year's free subscription to ENGINEERING MATERIALS AND DESIGN, commencing with this issue.

See page 224, for story and pictures of exhibition.

Three-dimensional Television

AN ADVANCED SYSTEM of stereoscopic closed-circuit television has been developed by E.M.I. Electronics Ltd. to meet the requirements of nuclear plants and other establishments where dangerous materials have to be manipulated remotely. The equipment utilises the company's standard closed-circuit units and consists of two camera channels mounted side-by-side and arranged to relay pictures on to two monitors. The pictures from these are then superimposed on each other by means of a mirror and polarised glass, to form a single image.

When viewed with polarised spectacles this produces a realistic three-dimensional picture. The equipment has already been demonstrated on the Continent and in this country, and has proved highly successful in practical demonstrations.

Features of the system include the simplicity with which it can be set up, and controlled, and the novel arrangement by which the human eye's "angle of squint" has been realistically achieved by mechanical means.

Engine Removed in 10 Mins.

A DESIGN which might well be followed in principle by motor car manufacturers has been announced by Leyland Motors Ltd. who recently demonstrated that the engine of the Atlantean 78 seater double-decker bus could be removed in 9 min. 50 sec. under normal workshop conditions. This compares with the time of about 8 hours which is usually taken to remove an engine from a conventional double-decker. Apart from two special hooks no unconventional tools were required and the success of this demonstration seems to have depended on efficient design in the sense that only the necessary minimum number of fixing bolts were used and electrical, fuel and air lines were coupled with quick-release connections that enabled the engine to be isolated quickly.

Electrostatic Finishing of Non-metals

IN THE EARLY PART of the twentieth century wax recordings were metallised by the use of carbon powder. The wax recordings were painted with a primer and then dusted with carbon powder. The parts were then placed in a copper plating tank, and with the carbon acting as a conductor, the wax-carbon coated parts were copper plated. The success of this process depended upon the even distribution of carbon powder. By means of this process the waxed part was then duplicated in metal.

Later plaster parts such as lamp bases, statues, plaques, etc., and baby shoes, were bronzed plated using the same technique of plating a non-conductive material. The plaster base was painted and then "dusted" either with carbon powder or metallic powders such as copper powder. It was important that the copper powder used had not oxidised as the oxide formed on the particles of powder would act as an insulator between each copper particle thereby preventing the transmission of current during the plating process. An improvement over this method was to add copper powder to a clear varnish, lacquers or synthetic. This mixture allowed metallic powder to float to the top of the film and made it possible to conduct current on the surface of the finish. Later silver powder was used and this improved the conductivity of the film as silver oxide does not act as an insulator between the particles of silver powder. However, the cost of silver made this type of conductive coating prohibitive for industrial use. In the late 1940's when electrical shielding was required on some electronic equipment, conductive coatings were used to replace copper sheet or copper plate. Conductive coatings were also used as electrical shields for parts made of wood.

Electrostatic finishing of wood and wood products is now possible with the use of a conductive primer. Electrostatic application of clear and pigmented lacquers, enamels, and synthetics are said to have increased production and reduced paint costs from 20 to 40 per cent.

A black conductive coating known as MV-991 and produced by Maas & Waldstein Co., can be applied as a primer by dip, flow coat or manual spray. This primer can be air dried or force dried after which the finish coat is applied by the electrostatic method. This finishing system can be used to good advantage where parts are hung on a conveyor and the conductive primer is applied automatically by dip, flow coat or manual spray. The parts are then conveyed through the electrostatic section for the application of the finish coat.

FOR FURTHER INFORMATION:—

Bakelite Ltd. 12-18 Grosvenor Gardens, London, S.W.1.
E.M.I. Electronics Ltd., Hayes, Middlesex.
Stanford Research Institute, Menlo Park, California.
National Bureau of Standards (O.T.I.) U.S. Dept. of Commerce, Washington 25, D.C.
U.K.A.E.A., Patents Exploitation Officer, 11 Charles II Street, London, S.W.1.
Leyland Motors Ltd., Leyland, Lancs.
G.E.C. Ltd., Erith, Kent.
Ateliers de Constructions Electriques de Charleroi, Belgium.
Mellowes & Co. Ltd., Bridge Street, Sheffield 3.
Sir W. G. Armstrong Whitworth Aircraft Ltd., Coventry.
Research Development Corp. of America, 120 West 154th Street, Gardena, Cal.
Lead Development Association, 18 Adam Street, London, W.C.2.
Babcock & Wilcox Co.: 161 E. 42nd Street, New York, N.Y.

THE BRITISH HAVE NO WORD FOR IT

NO apologies will be given for returning to a theme so often discussed on these pages—the status of the engineering designer—because the matter was frequently referred to at the Engineering Materials and Design Conference and this time the words are not ours. Several speakers commented in forthright terms, and we feel we cannot do better than to quote Mr. J. Shapiro who in his paper, "Engineering Design in Britain, Germany and Russia", compared the situation in this country, not with the United States as is usual, but with the position in central and eastern Europe. Mr. Shapiro said: "My thesis is not original, but is none the less strongly felt; namely, that the engineering designer in this country lacks recognition and what recognition he has is not increasing as it ought to increase."

In the discussion which followed several papers, it was clear that this general theme had the approval of the majority of delegates, as would be expected, but in trying to find the reasons for this state of affairs and a solution to the problem of improving the status of the designer many different opinions were expressed. We sympathise with designers who complain that they are underpaid, but we must also try to understand the viewpoint of management who have found that if they promote their designers or employ engineering graduates in the first place these men apparently find it degrading to work on a drawing-board. It seems that we must go back to the initial education and training of designers for the answer; immediately we run into difficulties because, while a general engineering education includes some drawing-board experience, a designer should face the fact that for him the board is more important than the desk, and therefore his training must be adjusted accordingly. Looking over the syllabuses of many engineering colleges, we fail to find that such a programme is being followed, although we have noted with interest the course on industrial design now running at Peel Park Technical College, where a serious attempt is being made to prepare the ground for designers of the future.

Mr. W. E. Walters, general secretary of the Institution of Engineering Designers, asks in an article in a recent issue of *The Financial Times*: "Is there any difference between an engineer and an engineering designer?" He points out that this is like asking the difference between a bird and a swan. All swans are birds, but not all birds are swans; similarly, all engineering designers are engineers, but not all engineers are designers. It has been pointed out by Mr. Hugh Clausen and others that we lack a single poignant and descriptive word to label the engineering designer. In this respect, both the Germans and Russians are better off, as are some other professions in the U.K. For instance, an architect is immediately respected and protected by his title and is not likely to be confused with bricklayers or carpenters, whereas the word "engineer" (whether holding a prefix "design" or some other denomination such as "maintenance") is often used to signify mechanic.

Some amusing moments can be had by pondering the alternatives suggested by Peter Roget's *Thesaurus*, which suggests "schemer", "projector" and "intriguant" as alternatives to "designer"! Obviously such words would invite rude comment and we feel that an altogether new word should be coined for this purpose, such as "formatist", to imply the giving of form, as a translation of the German word, *Gestaltung*. Whatever word might be used, and we feel that the correct choice is very important, it is equally vital that it should be protected by law from abuse by those not qualified to use it. While we cannot guarantee to introduce a special Act of Parliament to legalise the use of a new word, we would welcome our readers' views on this!

The Editor

HOW TO SELECT PERMANENT MAGNET MATERIALS

Three types of materials are currently available for designers to use for permanent magnets: alloy steels, dispersion-hardening alloys and ferrites. Their characteristics are compared here

by R. H. WARRING

WHILE the bulk of the present-day requirements for permanent magnets are met by the aluminium-nickel dispersion-hardening alloys with their high magnetic properties, i.e., the anisotropic Alcomax alloys and the isotropic alloys Alni and Alnico, these are subject to serious mechanical limitations and are only suitable for fabrication in cast or sintered forms with geometric restrictions. Thus a demand for alloy steel magnets continues, particularly where complexity of shape or intricacy of machining makes it impossible to employ magnets from the newer alloys and where reasonable, rather than outstanding, magnetic properties are called for. More recently, too, considerable advances have been made in the production of non-metallic or so-called "ceramic" magnets based on ferrites. The high coercivity of these materials permits very short length/section ratios, although remanence is low and the temperature characteristics unfavourable. Development of micropowder magnets has not yet approached the theoretical performances which should be realisable from an aggregate of single domains and (though listed in the accompanying tables) are not suggested for, nor readily available as, standard design materials.

A practical improvement in the performance of Alcomax-type alloys has been realised by rendering the material in both semi-columnar and fully columnar form by rigidly controlled heat treatment (cooling) to promote columnar crystal growth. At present, at least, such treatment is limited to relatively simple shapes and restricted sizes without sharp edges and with a complete absence of core holes, etc.

Other experiments with ferrites have resulted in the development of magnesium-manganese and copper-manganese ferrites with almost purely rectangular hysteresis loops, and a coercive force controllable by the degree of zinc ferrite introduced in the composition. In the absence of zinc ferrite, a coercive force of the order of 1·0 to 1·5 oersteds can be obtained, ranging down to as low as 0·2 by the addition of zinc ferrite. A considerable number of ferrite magnets of these types have found application in high-speed computers, etc.

The whole range of commercially available permanent magnet materials may be grouped, broadly, into three

TABLE I. Comparative properties of common permanent magnet materials

	Alloy Steel				Dispersion-hardening Alloys				Ferrites
Characteristics	Tungsten Steel	Chromium Steel	Cobalt-Chrome	Cobalt Steels	Isotropic	Anisotropic	Semi-columnar	Fully Columnar	
B_r BH_{max} H_c	High Low V. Low	High Low V. Low	High Low Low	High Low-High Moderate	High High High	High V. High V. High	V. High V. High V. High	V. High V. High V. High	V. Low Low V. High
Proportions	Long length/short section ratio				Compact. Low length/section ratio				Very short. Compact
Manufacture	From bar stock	Rolled bar. Also cast	Rolled or forged bar. Also cast	Cast, rolled or forged bar	Normally cast: Can be sintered / Cannot be sintered				Sintered
Machinability	Suitable for all operations			35% alloy not suitable for tapping or milling	Grinding only				Grinding only
Working limitations	Suscep. to cracking	Some suscep. to cracking	Free from cracking	Suscep. to flaking with high cobalt content	Not suitable for reworking				Not suitable for rework
Holes or threads	Easy	Easy	Easy	Avoid in 35% cobalt alloy	Holes cored or filled with soft metal for drilling, etc.		None permissible		None
Design limitations	Long length/short section ratio necessary				Avoid thin walls, abrupt changes of section, complex shapes		Simple column and cylinder shapes only		Compact shapes only
Normal size range	No limits				Cast magnets 1/10 oz. to 30-40 lb. Sintered* materials, 1 oz. max.				Small usually
Mechanical properties	Strong				Brittle				Brittle
Magnetic limitations	Low coercivity				—	Anisotropic			—
Approx. equiv. volume†	17	18	16	5.4—14.5	3-4	1.0	.80	—	1.7—4.4
Approx. equiv. weight†	19	19	17	6—15	3-4	1.0	.80	—	1.2—4.2
Typical application	High remanence, low cost magnets	Alt. to tungsten. Slightly inferior perf. but lower cost	Low perf. magnets but good mech. properties	Optimum perf. from machined magnets	First choice for isotropic permanent mag.	Normally first choice mat.	Where enhanced props. are of advantage	Special duty or v. high design needs	Electronics, small d.c. mots, etc., where energy constnt and p. temp. char. are imp.
Temperature stability	Varies with grade of material. Max. service temp. 100-250° C				Suitable for up to 550° C				Approx. 1% loss of B per 5° C temp. rise

* Sintered magnets have lower density and lower magnetic performance. † Based on working point at BH_{max}.

classes:

1. Alloy steels—usually fabricated by machining, etc.
2. Dispersion-hardening alloys—suitable only for casting or sintering.
3. Ferrites—as powder compacts, for sintering.

Table 1 designates sub-groups in each of these three main classes, together with generalised data, based on the accepted "standard" materials available.

While there is obviously a wide variety of different materials which can be developed as permanent magnets, the bulk of magnet materials produced in the U.K. are to a set series of materials specified by the Permanent Magnet Association and manufactured by its members and others. (Not every member of the P.M.A., however, necessarily manufactures all the standard P.M.A. materials. Some, for example, do not manufacture sintered magnets in any of the nickel-aluminium alloys.) Some confusion can arise from the fact that similar names are used by manufacturers in other countries to designate different alloys (e.g., Alnico V in the U.S.A. is virtually the equivalent of Alcomax II in the U.K.). Also, a variety of trade names have been adopted for materials closely related to "standard" materials by manufacturers in the U.K.

In presenting the data on magnetic materials and their performances, the following procedure has, therefore, been adopted:

1. Permanent magnet materials are grouped according to type, i.e., all materials in the same table or section of a table are of basically similar form.
2. Materials are arranged in descending order of B_r (remanence), irrespective of the other magnetic properties.
3. P.M.A. standard materials are designated in the first material column. Other British materials are listed in the centre material column and foreign materials in the third material column. Equivalents are read directly. Similarly, near-equivalents are readily assessed by comparison of specified magnetic properties, in order of remanence values.
4. Magnetic characteristics for all P.M.A. materials are based on current P.M.A. data, consistent with average performance of a number of test samples in rectangular block form.
5. All other material characteristics are quoted from manufacturers' data or similar sources. These may or may not be consistent with P.M.A. rating (e.g., American permanent magnet performance data are usually quoted as minimum guaranteed values). They can, however, be taken as satisfactory for comparative performances. Where specific performance is critical, it would be advisable to check performance data with the source (manufacturer).
6. Constituents, where given, assume that the balance of 100 per cent is iron.

Table 5 lists a variety of commercial permanent magnet alloys in order of remanence without reference to P.M.A. "equivalents". Such comparison as may be required can be done by comparing performance with Tables 2, 3 and 4. Similarly, Table 6 lists commercial ferrites separately, there being no direct comparison with alloy magnets. The two P.M.A. standard materials are Feroba I and Feroba II.

Magnetic performance figures in all the tables are quoted in c.g.s. units. Where it is necessary to convert to equivalent rationalised M.K.S. units, the following conversion factors apply:

Flux Density (B)

c.g.s. unit gauss $\times 10^{-4}$ = webers/sq. metre (M.K.S. units)

Magnetising Force (H)

c.g.s. unit oersteds $\times \frac{10^3}{4\pi}$ = ampere-turns/metre (M.K.S. units)

Energy Content (BH_{max})

c.g.s. units mega-gauss-oersteds $\times \frac{10^5}{4\pi}$ = joules/metre^3 (M.K.S. units)

TABLE 2. Alloy steel permanent magnet materials

ALLOY TYPE & DENSITY	PERMANENT MAGNET ASSN. MATERIAL	COMPOSITION	PROPERTIES B_r GAUSS	BH max MGO	H_c OERST.	OTHER BRITISH MATERIAL	COMPOSITION	FOREIGN MATERIAL	COMPOSITION
COBALT STEEL DENSITY RANGE 7.7–8.25	17½ COBALT STEEL	Cr 6 Co 17½ W 5 C 0.9	10,000	90	240			17½ COBALT STEEL: USA	Cr 4 W 5 C 0.7
			9,500	84	240			17½ COBALT STEEL: USA	Cr 4 W 5 C 0.7
								KS 100 - GERMANY HA 4 - BELGIUM H5 - COBALT - USA KS 1 - JAPAN KOBALT 300 - GERMANY HS 20 - SWITZERLAND KOBALT - HUNGARY KS 25/45 - GERMANY	Cr 4 W 5 C 0.9
	17½ COBALT STEEL	Cr 6 Co 17½ W 5 C 0.9	9,000	85	250				
			8,800	75	270	20½ COBALT STEEL	Cr 4 Co 20½ W 5 C 1		
			8,600	69	230			KS 200 - GERMANY EW - GERMANY	Cr 4 Co 20½ W 5 C 1
	15½ COBALT STEEL	Cr 6 Co 15½ W 5 C 1	8,200	62	180			HA 5 - BELGIUM KS 070 GERMANY KS 2 - JAPAN HS 15 SWITZERLAND KOBALT 200 - GERMANY 28/66/43	Cr 4 Co 15 W 5 C 1
			8,400	58	165			KS 105 - GERMANY K 11	Cr 4 Co 11 W 5 C 1
	9½ COBALT STEEL	Cr 6 Co 9½ W 5 C 1	7,800	50	160			KS 3 - JAPAN KOBALT 160 - GERMANY 25/54/43 - GERMANY	Cr 4 Co 9½ W 5 C 1
	6½ COBALT STEEL	Cr 6 Co 6½ W 5 C 1	7,500	44	145			HA 2 - BELGIUM Ro GERMANY HS 6 - SWITZERLAND KS 030 KOBALT 125 - GERMANY 28/60/43	Cr 4 Co 6 W 5 C 1
	3½ COBALT STEEL	Cr 6 Co 3½ W 5 C 1	7,200	33	130			HA 1 - BELGIUM KS 4 - JAPAN KS 045 KOBALT 100 - GERMANY 18/51/27	Cr 4 Co 3 W 5 C 1
COBALT CHROME STEEL 7.85	3½ CO 3½ CR STEEL	Cr 4 Co 3½ W 5 C 1	9,800	34	80			KS 040 K2 VH 18/32/40 - GERMANY	Cr 3 Co 4 W 6 C 1
CHROMIUM STEEL DENSITY RANGE 7.6–8.2	CHROMIUM STEEL	Cr 4 C 1	9,800	30	70		Cr 4 C 1	C K3 K 3030 12/40/46 HA9 - BELGIUM 37/28 STEEL - USA	Cr 3.5 W 6 C 1
			9,600	29	69				
			9,500	30	70	6½ CHROME STEEL	Cr 4 C 1	CR 40 STEEL - GERMANY CR 61 STEEL - GERMANY 14/13/46 CR 133 - GERMANY 5% CR STEEL	Cr 5 W 1 C 1
			9,400	30	65				
			9,000	29	65			3½ CHROME STEEL - USA	Cr 3.5 W 1 C 1
TUNGSTEN STEEL 8.1–8.7	6½ TUNGSTEN STEEL	W 6 Cr 6 C 0.7	10,500	30	65		W 6 C 1		
			8,800	25	60	17½ TUNGSTEN STEEL	W 17 C 1		
CARBON STEEL	CARBON STEEL[1]	C 1	9,000	28	50	CARBON STEEL	C 1	CARBON STEEL - USA	C 1

[1] OBSOLETE

TABLE 3. Nickel aluminium alloy materials

ALLOY TYPE & DENSITY	PERMANENT MAGNET ASSN. MATERIAL	COMPOSITION	PROPERTIES B_r GAUSS	BH max MGO	H_c OERST.	OTHER BRITISH MATERIAL	COMPOSITION	FOREIGN MATERIAL	COMPOSITION
ALUMINIUM-NICKEL-COBALT-(COPPER) DENSITY RANGE 6.9–7.3	ALNICO HIGH RCM	Al 10 Ni 17 Co 12 Cu 3.5	8,000	170	500			ALNICO IIC - USA	Al 10 Ni 17 Co 12 Cu 3.5
			7,600	140	490			ALNICO I - GUSA	Al 12 Ni 25 Cu 3
			7,380	180	700			ALNICO 100 - GERMANY	Al 11 Ni 24 Co 4
	ALNICO NORMAL	Al 10 Ni 19 Co 12 Cu 6	7,250	170	560	RECO 3 A	Al 10 Ni 19 Co 12 Cu 6	ALNICO II B - USA MAGNICO - BELGIUM RECO 3A - HOLLAND TICONAL 36 - HOLLAND	Al 10 Ni 19 Co 12 Cu 6
			7,100	140	450			ALNICO I B - USA	Al 12 Ni 21 Cu 3
			7,000	160	700			ORMAL - AUSTRIA	Al 10 Ni 20 Co 15 Cu 4
			6,600	140	540			ALNICO I A - USA	Al 12 Ni 25 Cu 3
	ALNICO HIGH COER	Al 10 Ni 21 Co 12 Cu 6	6,600	170	670	KYMCO	Al 10 Ni 21 Co 12 Cu 6	ALNICO II A - USA FAMA 700 - SWEDEN DERSTIT 700 - GERMANY	Al 10 Ni 21 Co 12 Cu 6
	ALNICO NORMAL SINTERED	Al 10 Ni 19 Co 12 Cu 6	6,500	170	640	RECO 3 A SINTERED	Al 10 Ni 19 Co 12 Cu 6	ALNICO II SINT - USA	Al 10 Ni 19 Co 12 Cu 6
			6,450	160	640			ALNICO 600 S - GERMANY	Al 16 Ni 24 Co 11 Cu 4
			6,400	145	630			ALNICO 160 - DERSTIT 160 - GERMANY 65/IN/27	Al 11 Ni 28 Co 8.5 Cu 5
			6,300	140	630			ORMAL 140 - AUSTRIA	Al 11 Ni 25 Co 8 Cu 3
			6,000	140	630			ALNICO IV B - USA	Al 12 Ni 26 Co 5 Cu 3
			6,000	165	700			ALNICO IV H - USA	Al 12 Ni 26 Co 9 Cu 2
			5,700	140	650			ALNICO 130 - GERMANY	Al 12 Ni 26 Co 5 Cu 4
			5,700	128	570			ALNICO 8DS - GERMANY	Al 14 Ni 24 Co 38 Cu 3
			5,300	135	700			ALNICO IV A - USA	Al 12 Ni 26 Co 5 Cu 3
			5,100	125	690			ALNICO 130S - GERMANY	Al 12 Ni 26 Co 5 Cu 4
			3,800	70	600			ALNICO 8DP - GERMANY	Al 14 Ni 24 Co 38 Cu 3
NICKEL-ALUM-COPPER DENSITY 6.9								ALCOMET 66 - SWITZ. ALNI 120 - GERMANY ALNICO 11C - USA FAMA 600 - SWEDEN RECO 1 - HOLLAND DALEX - HUNGARY	Ni 15 Al 13 Cu 4
	ALNI HIGH RCM	Ni 13 Al 24 Cu 4	6,200	125	490	~IDAL ~IDAL	Ni 15 Al 24 Cu 4		
	ALNI NORMAL	Ni 13 Al 25 Cu 4	5,800	115	380			NE - JAPAN IDAL - SOLAKEN	Ni 15 Al 25 Cu 4
	ALNI HIGH COER.	Ni 13 Al 27 Cu 4	5,500	125	630			ALNICO III A - USA	Ni 13 Al 27 Cu 4
			5,000	125	680				
			5,000	130	670	~HYDICAL SUPERMAG	Ni 20 Al		
NICKEL-ALUMINIUM DENSITY RANGE 6.5–6.9								ALNI 080 DERSTIT SPECIAL - GERMANY 65/2N/67	Ni 19 Al 12 Co 32
			7,000	90	380				
			6,600	120	515			ALNICO 500 - USA DERSTIT 500 - GERMANY 50/12/20 - GERMANY HYDRAL METAL - JAPAN	Ni 14 Al 8 Co 24 Cu 3
			5,800	110	380			ALNI 120 - GERMANY 28/12/20 - GERMANY IDAL 120 - AUSTRIA	Ni 20 Al 12 Co 27
			5,200	98	440			ALNI 120S - GERMANY	Ni 20 Al 12 Co 27
			4,400	48	230			TERMALIT 100 - GERMANY	Ni 22 Al 10 Co 27
			3,400	50	465			ALNI 120P TERMALIT	Ni 20 Al 12 Co 27
ALUMN-70			5,500	80	380			NT - JAPAN	Al 7 Ni 14

Alloy Steel Materials

Before the first decade of the present century, carbon steel was the standard permanent magnet material. Tungsten steels found extensive application with the development of the internal combustion engine for magneto units, with chromium steel developed by Germany as an alternative material during the First World War. Both alloys have rather similar magnetic performance and still continue to be used in a minority of older designs where magnetic efficiency is not a prior consideration.

Many magnets originally specified in tungsten steel (or chromium steel) are now made in chromium-cobalt steel, which is free from mechanical strain often associated with the earlier alloys.

Cobalt alloy steels offer enhanced performance with materials still fully tractable as regards machining, etc., and can be an attractive low-cost solution where reasonable magnetic properties are required from relatively small magnets of complex shape, etc., not amenable for casting or sintering in the modern alloys. Price and performance increase with increasing cobalt content, with a similar *decrease* in machining properties. There is a tendency for 35 per cent cobalt steel to be brittle and unsuitable for tapping. All machining operations on this material need extra care and milling is generally to be avoided, as it tends to produce flaking.

Nickel Aluminium Alloys

Table 3 covers the more important ternary alloys of iron, nickel and aluminium which yield isotropic properties and very high values of coercive force. The British Alni alloy is largely superseded by (British) Alnico, although Alni is still the cheapest of this group of alloys and may be preferred where a short magnet is desirable but minimum cross-section is not important.

Alnico (British) is the most powerful of the commercially available isotropic alloys. Note, however, that the name 'Alnico' is retained throughout the American range of anisotropic alloys (see Table 4).

All materials in this group have unfavourable mechanical properties in that they can be produced only by casting (or sintering) and are brittle, so that further fabrication is virtually restricted to grinding.

TABLE 4. Anisotropic alloy materials

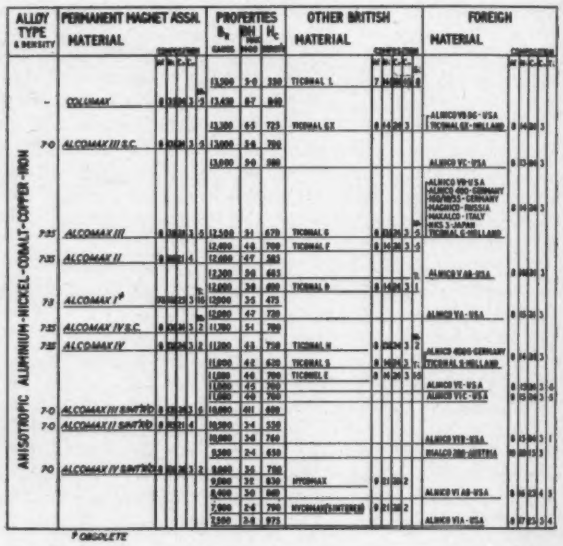


TABLE 5. Miscellaneous permanent magnet alloys

Material and Origin	Composition	B_r	BH_{max}	H_c	
P6 (U.S.A.)	6Ni 45Co 4V	14,000	0·30	55	Cold-worked alloy
Koerzit T (Germany), Vicalloy II (U.S.A.)	52Co 13V	10,000	2·80	450	Cold-worked alloy
Comalloy (Brit.), Remalloy (U.S.A.)	12Co 17Mo	10,000	1·10	230	Age-hardening alloy
Indalloy (U.S.A.)	12Co 17Mo	9,000	0·90	230	Age-hardening alloy
Vicalloy I (U.S.A.)	52Co 9·5V	9,000	1·00	300	Cold-worked alloy
Ticonal K (Holland)	34Co 18Ni 6Al 8Ti	8,500	3.20	1,100	Titanium casting alloy
Gaussit 180 (Germany)	50Co 14V	8,000	1·40	250	Cold-worked alloy
Alnico VII (U.S.A.)	30Co 18Ni 8·5Al 5Ti 3Cu	7,500	3·00	1,050	Cast alloy
MO I (Japan)	23Mo 2·5Cr	7,000	0·80	250	Age-hardening alloy
Stainless steel (Brit.)	12Ni 12Cr 0·15C	7,000	0·19	60	Cold-worked alloy
Cunife II (U.S.A.)	20Ni 50Cu 2·5Co	7,000	0·78	260	Cold-worked alloy
Honda alloy KS (Japan)	27Co 18Ni 7Ti 4Al	6,500	2·00	900	Cast alloy
Oerstit 800 80/9/36 (Germany)	19Co 8Ni 9Al 4Cu 4Ti	6,500	1·90	750	Cast alloy
Alnico 250 (Germany)	24Co 19Ni 7Al 5Ti 3Cu	6,200	2·30	1,000	Cast alloy
Oerstit 1000 85/7/35 (Germany)	35Co 18Ni 8Ti 6Al	6,000	1·80	950	Cast alloy
Alnico 250S (Germany)	24Co 19Ni 7Al 5Ti 3Cu	5,600	2·03	915	Sintered
Reco 2A (Holland), Reco 2A (Brit.), Fama 100 (Sweden)	20Co 20Ni 7Al 7Cu 6·5Ti	5,500	1·90	1,000	Cast alloy
Hynico II (Brit.)	20Co 20Ni 8Al 4Ti 0·8Nb	5,500	1·60	950	Cast alloy
Cunico II (U.S.A.)	41Co 35Cu 24Ni	5,300	1·00	450	Cold-worked alloy
Cunife I (U.S.A.), Magnetoflex 20 (Germany)	60Cu 20Ni	4,800	1·00	440	Cold-worked alloy
Alnico 250P (Germany)	24Co 19Ni 7Al 5Ti 3Cu	4,500	1·00	850	Powder
Magnetoflex 12 (Germany)	68Cu 20Ni	3,600	1·00	680	Cold-worked alloy
Cunico I (U.S.A.), Permet (U.S.A.)	21Ni 29Co 50Cu	3,400	0·85	710	Cold-worked alloy
Stainless steel (Brit.)	18Cr. 8Ni 0·15C	3,000	0·35	250	Cold-worked alloy
Heusler alloy (U.S.A.), Silmanal (U.S.A.)	86·7Ag 8·8Mn 4·5Al	550	0·08	540	Silver alloy

TABLE 6. Non-metallic ferrites

Material and	Composition	Magnetism	B_r	BH_{max}	H_c	Density
Bismanol (U.S.A.)	bismuth-manganese	Anisotropic	4,000	4·00	3,600	—
Kato's oxide (Japan)	cobalt ferrite	—	4,000	1·00	500	—
Feroba II (Brit.)	barium ferrite	Anisotropic	3,500	3·00	1,800	4·8
Magnadur II (Holland)	,, ,,	,,	3,500	2·30	1,350	4·8
Magnadur III (Holland)	,, ,,	,,	3,000	2·20	1,950	4·8
Feroba I (Brit.)	,, ,,	Isotropic	2,000	0·80	1,600	4·8
Caslox II (Brit.)	,, ,,	,,	2,000	0·80	1,600	4·8
Magnadur I (Brit.)	,, ,,	,,	2,000	0·80	1,600	4·8
Ferroxdure (Holland)	,, ,,	,,	2,000	0·80	1,600	4·8
Ceramagnet, Cromag, Ferrimag I, Indox (U.S.A.)	,, ,,	,,	2,000	0·80	1,600	4·8
Gaussit 1600, Keorox (Germany)	,, ,,	,,	2,000	0·80	1,600	4·8
Vectolite (U.S.A.)	cobalt ferrite	,,	1,600	0·50	900	3·1
Caslox III (Brit.)	barium ferrite	,,	1,400	0·40	700	3·5
Caslox I (Brit.)	cobalt ferrite	,,	1,100	0·21	700	3·2

TABLE 7. Representative list of micropowders. There is no P.M.A. standard material in this group

Material and Origin	Density	B_r	BH_{max}	H_c
HR (Britain)	5·2	9,500	1·50	375
MR (Britain)	4·5	7,000	0·75	320
PF2 (France)	—	7,000	1·70	500
Hyflux (U.S.A.)	4·9	6,500	0·97	390
HC (Britain)	4·2	5,500	1·25	575
PFI (France)	—	5,000	1·10	475
MC (Britain)	4·0	4,000	1·00	500

Anisotropic Alloys

These alloys possess high magnetic stability and exceptional magnetic properties. Magnetic anisotrophy is produced by subjecting the alloy to a magnetic field during heat treatment (cooling), the resulting material showing enhanced magnetic properties along a specific "preferred" axis. Magnetic properties along planes perpendicular to this axis are considerably reduced. This may represent certain limitations as regards design and application, but the bulk of current demand for permanent magnets is usually from materials in this group.

Of the three standard P.M.A. materials, Alcomax II is the cheapest and the most popular. Alcomax III is preferred where a minimum size of magnet is essential. Alcomax IV is again rather more expensive but specifically applicable to designs where magnet length must be a minimum because of its high coercive force.

An important point to consider is that these materials (together with Alni and Alnico) may be sintered instead of cast, often with greater liberty in design. However, the magnetic properties of the sintered alloy are invariably inferior to the cast alloy. Thus, sintered Alcomax III, for example, is inferior in magnetic properties to cast Alcomax II.

The semi-columnar versions of Alcomax III and IV offer enhanced performance at a higher but still essentially commercial price. Columax magnets are expensive because of the complicated production technique involved, and shapes available are strictly limited.

Miscellaneous Alloys

These are grouped simply in descending order or remanence and cover the chief range of commercial cold-worked, age-hardening and titanium-containing casting alloys not covered by the previous grouping.

Non-Metallic Ferrites

Suited mainly for sintering in squat, compact forms, ferrites can be rendered both isotropic and anisotropic. These are particularly attractive for applications demanding a high coercive force and where other magnetic properties may not be of prime importance. Their main limitation is their marked sensitivity to temperature.

Micropowders

Little application appears to be made of these materials in current designs and their present availability is questionable. A particular problem, from the production point of view, appears to be the difficulty associated in arriving at suitable, extremely finely divided iron particles of correct shape, aligned correctly for optimum performance.

PRINCIPAL U.K. MANUFACTURERS

MEMBERS OF PERMANENT MAGNET ASSOCIATION

Edgar Allen & Co. Ltd.
Darwins Ltd.
English Steel Corporation Ltd.
H. Johnson Foster Ltd.
William Jessop & Sons Ltd.
Swift, Levick & Sons Ltd.
Peat, Marwick, Mitchell & Co.
Marrison & Catherall Ltd.
W. L. Marrison Ltd.
James Neill & Co. (Sheffield) Ltd.
Sheffield Magnet Co. Ltd.
Sheffield Steel Products Ltd.
Turton Bros. & Matthews Ltd.
Watson, Saville & Co. Ltd.

NON-P.M.A. MANUFACTURERS

Mullard Ltd.
Murex Ltd.
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The central research laboratories of the Permanent Magnet Association (84 Brown Street, Sheffield, 1) carry out research into all aspects of permanent magnet materials.

SIMPLIFIED GEAR CALCULATIONS

Design data for spur gear measurement is presented in this article, together with some simplified methods of calculation for the designer who is occasionally called upon for such work

by W. A. A. WITHAM, A.M.I.E.D.,* and A. G. BEAVERIDGE, Grad.I.Mech.E.†

THESE notes represent only a few of the methods which may be found useful in calculating various dimensional checks in connection with gear production. Much of the information given will be found in standard works on gearing, but, unfortunately, seldom under the same cover. Standard symbols have been adhered to in the diagrams, and since those likely to use this information will already be familiar with gear problems, it is not intended in this article to do more than outline the trigonometrical proofs. There are, of course, other methods of arriving at the same required information, but in many of these it has been observed that the equations are much more cumbersome and the arithmetic tedious. In the following methods, which give results accurate to six decimal places, most of the arithmetic involved is addition and subtraction, and a little interpolation in using the involute function tables. Seven-figure mathematical tables should be used.

The Involute Function

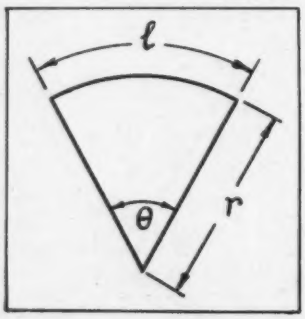
An involute curve is the path of a point on a cord which is held taut and unwound from a cylinder; alternatively, it may be defined as the locus of a point on a straight line which rolls, without slipping, on the circumference of a circle.

Referring to Fig. 1, if ψ is the pressure angle of the gear, then the angle subtended by the arc AC is entirely dependent upon the size of ψ and the values of the pitch circle radius and base circle radius. This angle is called the involute function of the pressure angle.

It will also be seen from Fig. 1 that the involute function considered is the one taken at the pitch circle radius. However, it is sometimes required to calculate the value of the involute function of an angle where the point "A" does not coincide with the pitch circle. This is easily done, if the radius at which the function is required is known, and also the base circle radius.

Radians

Since many of the calculations in gearing involve radian measure, it might be useful as a reminder to note that if:



l = length of arc
r = radius
θ = angle subtended (in radians)

π radians $= 180°$

Then $l = r\theta$

Hence $\theta = \frac{l}{r}$ and $r = \frac{l}{\theta}$

From Fig. 1 it will be seen that an involute gear tooth form has been struck from the base circle (tangential at B) and by definition of the involute, arc AB must equal A_1B.

r = pitch circle radius
r_0 = base circle radius
$= \frac{\text{P.C. dia} \times \cos. \text{ pressure angle}}{2}$

Let r_0 (base circle radius) = 1 unit
Arc AB = angle θ (in radians)
Also Arc AB = A_1B
Arc CB = angle ψ in radians

$$\text{Tan } \psi = \frac{A_1B}{\text{B.C.R.}}$$

$= A_1B = AB$ (B.C.R. = 1 unit)

Involute ψ = AB − CB
Inv ψ = tan ψ − ψ (radians)

Involute Tables

Referring to Fig. 1 again, it will be seen that the ratio

$$\frac{r}{r_0} = \frac{A_1O}{BO} = \text{secant } \psi$$

Shown in Table 1 is a section of the polar involute function tables (which are set out fully at the end of this article). To use the tables, the ratio $\frac{r}{r_0}$ must be calculated, where

r = pitch circle radius (or the radius at which value is required)
r_0 = base circle radius (see above) and pressure angle $\psi = 20°$

Example

Given B.C.R. (r_0) = 1·5,

$$\text{then } r = \frac{1{\cdot}5}{\cos \psi} = \frac{1{\cdot}5}{\cos 20°}$$

$$= \frac{1{\cdot}5}{0{\cdot}9396926}$$

$$= 1{\cdot}53315$$

Now $r = 1{\cdot}53315$
$r_0 = 1{\cdot}5$

then $\frac{r}{r_0} = \underline{1{\cdot}0221}$

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In Table 1 the value 1·02 is taken from the column marked "X", the next part of the value 0·002 at "Y". This gives 1·022. To find 1·0221 we have to interpolate with the next value, 1·0223. The final value 0·0030669 is the involute ψ in radians. The process can, of course, be reversed, starting with ψ to find r/r_0.

At intersection of "X" and "Y" value at 1·022 = 0·003046
at 1·023 = 0·003255

$\therefore$ difference = 0·000209

0·0001 (or 1/10th difference) = 0·0000209
add 1·022 = 0·003046
(above)
= 0·0030669
(adding)

Much more elaborate tables can be found in H. E. Merritt's *Gears* which will eliminate some of the interpolation above, and give greater accuracy, but the table given here will be found adequate for most uses.

To Calculate Distance Over "N" Teeth

Given: Base circle radius r_0
Number of teeth N
Pressure angle ψ
Backlash on one gear "x"

Then in Fig. 4

$$AX = \tan\psi - (\psi \text{ in radians}) \times r_0$$

$$XD = \frac{[\text{Angle of } (N-1) \text{ tooth pitches} + \text{angle of 1 tooth thickness at P.C.D.}] \text{ radians} \times r_0}{2}$$

Hence AD = AX + XD = half distance across N teeth.
$\therefore$ Distance across N teeth = 2 (AX + XD)
Backlash on one gear = x
Therefore, measurement over N teeth will vary between
2(AX + XD): high limit
and
2(AX + XD) − x: low limit.

Note: Allowed backlash may also be calculated from B.S. 436 (1940) where δ = tolerance factor $= \left[\frac{T+60}{10P} + 1\right]$ in thousandths of an inch and, for example, a high-class cut gear varies an amount under the nominal size of from δ (high) to 4δ (low), where T = no. of teeth and P = diametral pitch.

TABLE 1. Extract from involute function tables *(See page 216)*

		Y			
	r/r_0	·000	·001	·002	·003
	1·00				
	1·01				
X	1·02			·003046	·003255
	1·03				

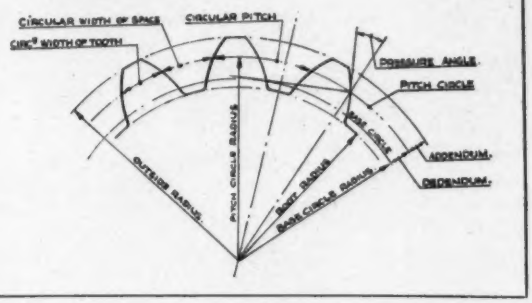
INTERPOLATE FOR ·0001

VALUE AT 1·0220

VALUE AT (r/r_0) 1·0221 = ·0030669 (SEE TEXT).

USEFUL FORMULAE FOR SPUR GEAR PROPORTIONS

1. Diametral pitch $= \frac{\text{No. of teeth}}{\text{P.C. dia}}$ or $\frac{\pi}{\text{circular pitch}}$
2. Pitch circle dia. $= \frac{\text{circular pitch} \times \text{No. of teeth}}{\pi}$
3. Addendum $= \frac{1}{\text{diametral pitch}}$ or $\frac{\text{circular pitch}}{\pi}$
4. Clearance $= \frac{0{\cdot}157}{\text{diametral pitch}}$ or $\frac{0{\cdot}157 \times \text{circular pitch}}{\pi}$ or $\frac{\text{circular pitch}}{20}$
5. Dedendum = Addendum + clearance or $\frac{1{\cdot}157}{\text{diametral pitch}}$
6. Circular thickness of tooth $= \frac{\text{circular pitch}}{2}$ (minus running backlash)
7. Base circle diameter = P.C. dia. × cosine pressure angle



Example

In the following examples it is intended to use the same basic gear data throughout in order to make the methods clear.

Gear Data Given P.C. dia. = 5 in.
N = 20 teeth
D.P. = 4
ψ = 20°
Backlash = 0·002/0·005 in. per pair

DISTANCE OVER THREE TEETH

Base circle rad. = P.C. rad × cos 20°
= 2·5 × 0·9396926
= 2·3492315 in.

Angle per tooth = 18° (20 teeth)

	Logs
AX = 0·0149324 × 2·3492315	$\bar{2}$·1741296
	0·3709256
= 0·0350796	$\bar{2}$·5450552

XD = 22½° (to radians) × B.C.R.

= 0·3926991 (degrees to radians tables)	
× 2·3492315	0·3709256
	$\bar{1}$·5940598
= 0·92254	$\bar{1}$·9649854

AD = 0·92254
0·0350796
0·9576196
×2
1·9152392

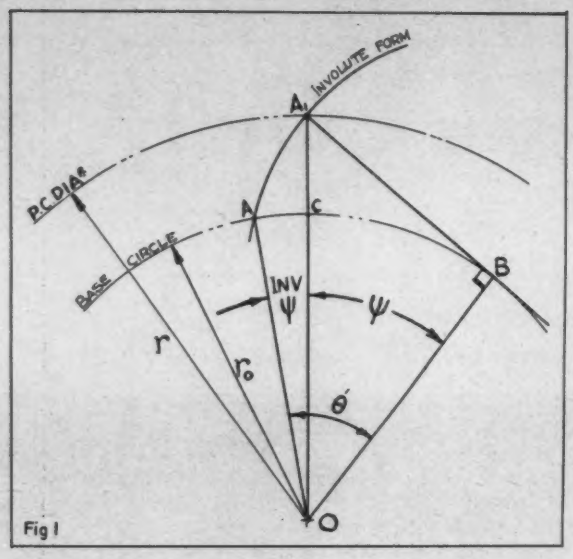


Fig 1

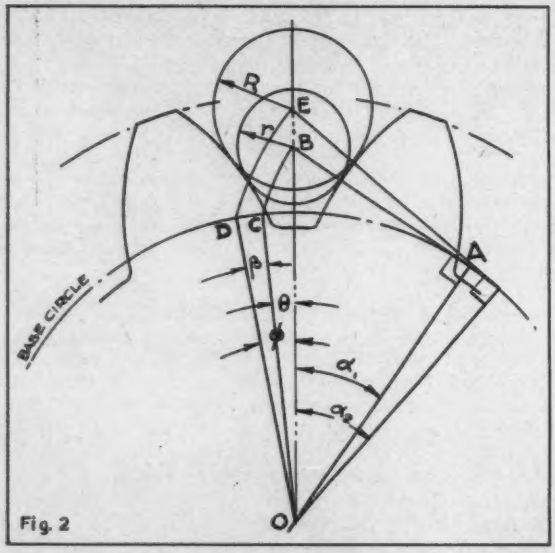


Fig. 2

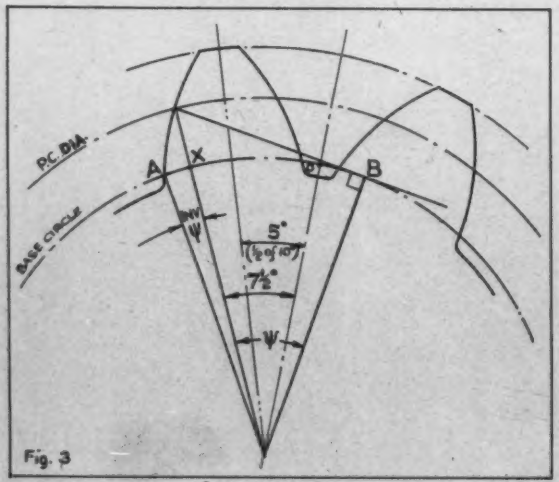


Fig. 3

Backlash on one gear = 0·001/0·0025

1·9152	1·9152
0·001	0·0025
1·9142	1·9127

To Calculate Distance over Rollers when Number of Teeth is Already Known (See Fig. 5)

Given: Base circle rad. r_0
Dia. of rollers D
Number of teeth N
Distance over N teeth = AB

$$\text{Arc AB in radians} = \frac{AB}{r_0}$$

$$\text{Arc HA} = \text{radius of roller} = \frac{D}{2} = \frac{\frac{D}{2}}{r_0} \text{ radians.}$$

θ = angle of (N−1) teeth (in radians)

$$IO = \frac{\text{angular pitch}}{2} \times r_0 \text{ (in radians)}$$

$$AO = \frac{AB - \theta}{2} = \beta \quad \text{(in radians)}$$

$$\text{Inv } \omega = \beta + HA - IO \quad \text{(in radians)}$$

Knowing inv ω, $\frac{r}{r_0}$ (or secant ω) can be found in the tables of involute functions.

Dimension over rollers = $2(r_0 \sec \omega) + D$

Note: The above calculation applies to a gear with an *even* number of teeth. If the number of teeth is *odd*, the calculation for the dimension over rollers would be completed as follows (see Fig. 6):

The calculation is carried out as above up to finding a value for 2 (r_0 secant ω) + D, then, referring to Fig. 6,

$$OX = \text{B.C.R.} \times \text{secant } \omega$$

$$\theta = \left(180° - \frac{\text{angular pitch of teeth}}{2}\right) \times \tfrac{1}{2}$$

$$XY = OX \sin \theta$$

∴ dimension over rollers = 2(XY) + dia. of roller.

To Find Dimension Over 0·432 in. Dia. Rollers

Distance over 3 teeth = 1·9142/1·9127 in.
Arc AB = 1·9142 or 1·9127 (see top of page)

AB in radians to radius 1. $\left(\text{Radians} = \frac{\text{Length of arc}}{\text{radius}}\right)$

$$= \frac{1{\cdot}9142}{2{\cdot}3492315} \text{ or } \frac{1{\cdot}9127}{2{\cdot}3492315}$$

		Logs
AB =	0·8142 or 0·814181	0·2819873
		0·3709256
		$\bar{1}$·9110617
		0·2816469
		0·3709256
		$\bar{1}$·9107213

HA = 0·216 in. in radians to radius 1 — $\bar{1}\cdot3344538$

$$= \frac{0\cdot216}{2\cdot3492315} = 0\cdot091946 \qquad \begin{array}{r} 0\cdot3709256 \\ \hline 2\cdot9635282 \end{array}$$

θ = angle of two teeth = 36° = 0·6283185 radians

IO = half pitch = 9° = 0·1570796 radians

			Logs
AB =	0·81482 or	0·814181	
θ =	0·6283185	0·6283185	
	2)0·1865015	2)0·1858625	
AO = β =	0·0932507 or	0·0929312	
HA =	0·091946	0·091946	
HO =	0·1851967	0·1848772	
IO = φ =	0·1570796	0·1570796	
Thus inv ω =	0·0281171	0·0277976	0·3709256
			0·0409691
			0·4118947

Thus secant ω = 1·09894 or 1·098169

Dimension = 2(B.C.R. × secant ω) + dia. of roller.

		Logs
2(2·5816)+0·432	2(2·57986) + 0·432	0·3709256
5·1632	5·15972	0·0406697
0·432	0·432	0·4115953
5·5952	5·59172	

Therefore dimension over 0·432 in. dia. rollers = 5·5917 in./5·5952 in.

(*Note*: Additional calculation required if there is an *odd* number of teeth in the gear.)

To Calculate Dimension over New Rollers when Dimension over Old Rollers is Already Known (see Fig. 2)

Given: Basic gear data, as before.

OA = r_0 (B.C.R.)

r = Radius of roller quoted.

R = Radius of roller to be used.

$$OB = \frac{(\text{distance over known rollers} - 2r)}{2}$$

$$\text{Cos } \alpha_1 = \frac{OA}{OB}$$

$$\text{Inv } \theta = \tan \alpha_1 - (\alpha_1 \text{ in radians})$$

$$\text{Angle } \beta \text{ (radians)} = DC = \frac{R - r}{OA} \text{ (radians) i.e., difference of roller radii}$$

Angle φ (radians) = $\theta + \beta$

Knowing φ radians and using tables, the value derived will be secant α_2

$$OE = r_0 \times \text{secant } \alpha_2$$

Hence, distance over rollers = 2OE + 2R.

Example

Diameter of new rollers = 0·4375 in. ($\frac{7}{16}$ in.)

OA = 2·3492315 in. r = 0·216 in. R = 0·21875 in.

OB = 2·57985 in. or 2·5816 in.

			Logs
$\text{Cos } \alpha_1 = \frac{2\cdot3492315}{2\cdot57985}$	or	$\frac{2\cdot3492315}{2\cdot5816}$	0·3709256
			0·4115945
			$\bar{1}$·9593311
= 0·910608	or	0·90999	
			0·3709256
$\therefore \alpha_1 =$ 24° 24·7′	or	24° 30′	0·4118890
			$\bar{1}$·9590366

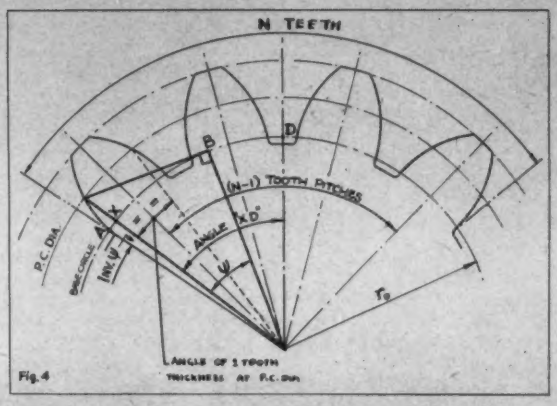


Fig. 4

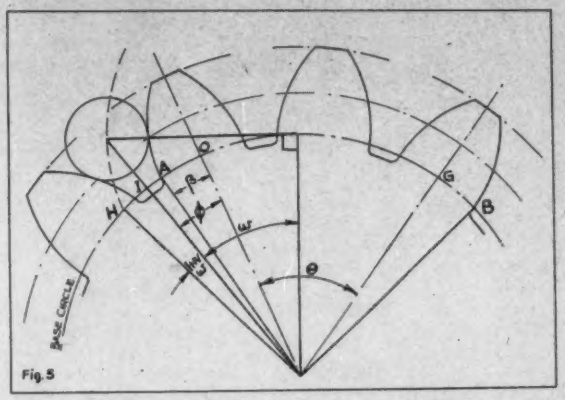


Fig. 5

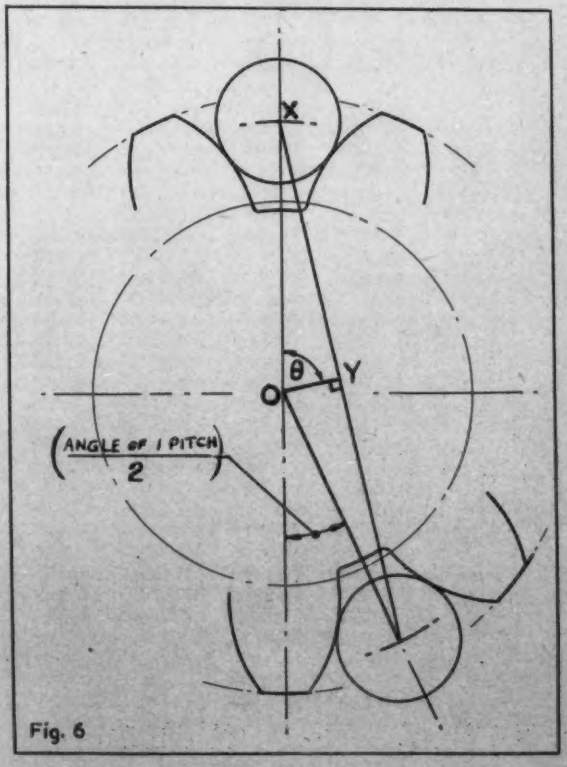


Fig. 6

Inv α_1 = Tan 24° 24·7′ − (24° 24·7′ in radians)
or Tan 24° 30′ − (24° 30′ radians)

		Logs
=	0·4538651	0·4557263 (Tables)
	0·4260639	0·4276057
	0·0278018	0·0281206

Angle $\beta = \frac{R - r}{OA} = \frac{0{\cdot}00275}{2{\cdot}3492315} = 0{\cdot}0011706$ — $\bar{3}{\cdot}4393327$ + $0{\cdot}3709256$ = $\bar{3}{\cdot}0684071$

Angle φ = Inv $\alpha_1 + \beta$

=	0·0278018	0·0281206
	0·0011706	0·0011706
	0·0289724	0·0292912

From Table 2

Secant α_2 = 1·100984 or 1·10175

OE = 2·3492315 × 1·100984 or
2·3492315 × 1·10175

		Logs
=	2·5864647 or 2·58826	0·3709256
		0·0417810
2OE =	5·1729294 or 5·17652	0·4127066
		0·3709256
Hence, 2OE + D =	5·17293 or 5·17652	0·0420830
	0·4375 0·4375	0·4130086
	5·61043 or 5·61402	

Dimension over 0·4375 in. dia. rollers = 5·6104 in./5·6140 in.

The following additional example, to find the distance over two teeth, is given as an alternative method of setting out the calculations which might be preferred (see Fig. 7).

To find Distance over two Teeth

Given B.C.R. (r_0) = 1 in.
N, number of teeth = 36 (i.e., 10° per tooth)
Pressure angle ψ = 20°
Backlash = 0·005 per pair (i.e., 0·0025 per tooth)

Referring to Fig. 3, it will be seen that since there are 36 teeth (10°) per tooth, the angles 5° and 7½° can be found by inspection and

AX = tan ψ − (ψ in radians) × r_0 (1in.) = 0·0149
XD = 7½° (in radians) × r_0 (1 in.) = 0·1309

∴ AD = (AX + XD) = half distance across teeth = 0·1458
∴ Distance across teeth = 2(AX+XD) = 0·2916
Backlash on one gear = 0·0025
∴ Measurement over 2 teeth = 2 (AX + XD) = 0·2916 high limit

and

2 (AX +XD) − 0·0025 = 0·2916 − 0·0025 = 0·2891 low limit

POLAR INVOLUTE FUNCTION TABLES

$\frac{r}{r_0}$ (r=p.c.rad. or rad. at which value reqd. r_0=B.C. rad.)	0·000	0·001	0·002	0·003	0·004	0·005	0·006	0·007	0·008	0·009
1·00	0·000	0·00003	0·000084	0·000155	0·000238	0·000330	0·000437	0·000550	0·000672	0·000802
1·01	0·000939	0·001082	0·001233	0·001389	0·001552	0·001720	0·001895	0·002074	0·002259	0·002448
1·02	0·002643	0·002842	0·003046	0·003255	0·003468	0·003686	0·003907	0·004133	0·004363	0·004596
1·03	0·004834	0·005076	0·005321	0·005570	0·005822	0·006078	0·006338	0·006601	0·006868	0·007137
1·04	0·007410	0·007686	0·007966	0·008249	0·008534	0·008823	0·009115	0·009410	0·009707	0·010008
1·05	0·010312	0·010618	0·010927	0·011239	0·011554	0·011871	0·012191	0·012514	0·012839	0·013167
1·06	0·013497	0·013830	0·014165	0·014503	0·014844	0·015286	0·015531	0·015879	0·016229	0·016581
1·07	0·016936	0·017293	0·017652	0·018013	0·018377	0·018743	0·019111	0·019481	0·019854	0·020228
1·08	0·020605	0·020984	0·021365	0·021748	0·022133	0·022519	0·022908	0·023299	0·023692	0·024087
1·09	0·024484	0·024883	0·025284	0·025686	0·026091	0·026498	0·026906	0·027310	0·027728	0·028142
1·10	0·028558	0·028979	0·029400	0·029822	0·030243	0·030664	0·031094	0·031523	0·031953	0·032382
1·11	0·032812	0·033250	0·033688	0·034127	0·034565	0·035003	0·035449	0·035896	0·036342	0·036789
1·12	0·037235	0·037689	0·038143	0·038598	0·039052	0·039506	0·039968	0·040430	0·040891	0·041353
1·13	0·041815	0·042284	0·042754	0·043223	0·043693	0·044162	0·044639	0·045115	0·045592	0·046068
1·14	0·046545	0·047029	0·047512	0·047996	0·048479	0·048963	0·049454	0·049944	0·050435	0·050925
1·15	0·051416	0·051913	0·052410	0·052908	0·053405	0·053902	0·054406	0·054909	0·055413	0·055916
1·16	0·056420	0·056930	0·057440	0·057949	0·058459	0·058969	0·059485	0·060001	0·060517	0·061033
1·17	0·061549	0·062071	0·062593	0·063116	0·063638	0·064160	0·064688	0·065216	0·065744	0·066272
1·18	0·066800	0·067334	0·067868	0·068401	0·068935	0·069469	0·070008	0·070547	0·071087	0·071626
1·19	0·072165	0·072710	0·073255	0·073799	0·074344	0·074889	0·075439	0·075989	0·076539	0·077089
1·20	0·077639	0·078195	0·078750	0·079306	0·079861	0·080417	0·080977	0·081538	0·082098	0·082659
1·21	0·083219	0·083784	0·084350	0·084915	0·085481	0·086046	0·086616	0·087187	0·087757	0·088328
1·22	0·088898	0·089473	0·090049	0·090624	0·091200	0·091775	0·092355	0·092935	0·093514	0·094094
1·23	0·094674	0·095259	0·095843	0·096428	0·097012	0·097597	0·098186	0·098775	0·099364	0·099953
1·24	0·100542	0·101136	0·101729	0·102323	0·102916	0·103510	0·104108	0·104706	0·105303	0·105901
1·25	0·106499	0·107101	0·107703	0·108306	0·108908	0·109510	0·110116	0·110722	0·111329	0·111935
1·26	0·112541	0·113151	0·113762	0·114372	0·114983	0·115593	0·116207	0·116822	0·117436	0·118051
1·27	0·118665	0·119284	0·119902	0·120521	0·121139	0·121758	0·122380	0·123002	0·123625	0·124247
1·28	0·124869	0·125495	0·126121	0·126748	0·127374	0·128000	0·128630	0·129260	0·129889	0·130519
1·29	0·131149	0·131783	0·132416	0·133050	0·133683	0·134317	0·134954	0·135591	0·136229	0·136866

POLAR INVOLUTE FUNCTION TABLES (*Contd.*)

$\frac{r}{r_0}$ r=p.c.rad. or rad. at which value reqd. r_0=B.C. rad.	0·000	0·001	0·002	0·003	0·004	0·005	0·006	0·007	0·008	0·009
1·30	0·137503	0·138144	0·138784	0·139425	0·140065	0·140706	0·141350	0·141994	0·142639	0·143283
1·31	0·143927	0·144575	0·145223	0·145870	0·146518	0·147166	0·147817	0·148468	0·149119	0·149770
1·32	0·150421	0·151075	0·151730	0·152384	0·153039	0·153693	0·154351	0·155009	0·155666	0·156324
1·33	0·156982	0·157643	0·158304	0·158966	0·159627	0·160288	0·160952	0·161616	0·162279	0·162943
1·34	0·163607	0·164274	0·164941	0·165608	0·166275	0·166942	0·167612	0·168283	0·168953	0·169624
1·35	0·170294	0·170967	0·171641	0·172314	0·172988	0·173661	0·174337	0·175013	0·175690	0·176366
1·36	0·177042	0·177721	0·178401	0·179080	0·179760	0·180439	0·181121	0·181803	0·182484	0·183166
1·37	0·183848	0·184533	0·185218	0·185903	0·186588	0·187273	0·187961	0·188648	0·189336	0·190023
1·38	0·190711	0·191402	0·192092	0·192783	0·193473	0·194164	0·194857	0·195550	0·196244	0·196937
1·39	0·197630	0·198326	0·199022	0·199718	0·200414	0·201110	0·201809	0·202507	0·203206	0·203904
1·40	0·204603	0·205304	0·206005	0·206707	0·207408	0·208109	0·208813	0·209516	0·210320	0·210923
1·41	0·211627	0·212333	0·213039	0·213746	0·214452	0·215158	0·215867	0·216576	0·217284	0·217993
1·42	0·218702	0·219413	0·220124	0·220836	0·221547	0·222258	0·222972	0·223685	0·224399	0·225112
1·43	0·225826	0·226542	0·227258	0·227974	0·228690	0·229406	0·230124	0·230843	0·231561	0·232280
1·44	0·232998	0·233719	0·234440	0·235160	0·235881	0·236602	0·237325	0·238048	0·238770	0·239493
1·45	0·240216	0·240941	0·241667	0·242392	0·243118	0·243843	0·244570	0·245298	0·246025	0·246753
1·46	0·247480	0·248210	0·248940	0·249669	0·250399	0·251129	0·251861	0·252593	0·253324	0·254056
1·47	0·254788	0·255522	0·256256	0·256990	0·257724	0·258458	0·259194	0·259930	0·260667	0·261403
1·48	0·262139	0·262877	0·263615	0·264354	0·265092	0·265830	0·266570	0·267311	0·268051	0·268792
1·49	0·269532	0·270274	0·271016	0·271759	0·272501	0·273243	0·273987	0·274732	0·275476	0·276221
1·50	0·276965	0·277711	0·278458	0·279204	0·279951	0·280697	0·281445	0·282194	0·282942	0·283691
1·51	0·284439	0·285189	0·285939	0·286690	0·287440	0·288190	0·288942	0·289694	0·290447	0·291199
1·52	0·291951	0·292705	0·293459	0·294213	0·294967	0·295721	0·296477	0·297233	0·297989	0·298745
1·53	0·299501	0·300259	0·301016	0·301774	0·302531	0·303289	0·304049	0·304808	0·305568	0·306327
1·54	0·307087	0·307849	0·308610	0·309372	0·310133	0·310895	0·311658	0·312421	0·313184	0·313947
1·55	0·314710	0·315475	0·316240	0·317005	0·317770	0·318535	0·319302	0·320068	0·320835	0·321601
1·56	0·322368	0·323136	0·323905	0·324673	0·325442	0·326210	0·326980	0·327750	0·328520	0·329290
1·57	0·330060	0·330832	0·331604	0·332375	0·333147	0·333919	0·334692	0·335466	0·336239	0·337013
1·58	0·337786	0·338561	0·339336	0·340111	0·340886	0·341661	0·342438	0·343214	0·343991	0·344767
1·59	0·345544	0·346322	0·347101	0·347879	0·348658	0·349436	0·350216	0·350996	0·351775	0·352555
1·60	0·353335	0·354117	0·354899	0·355682	0·356464	0·357246	0·358028	0·358810	0·359593	0·360375
1·61	0·361157	0·361942	0·362727	0·363513	0·364298	0·365083	0·365868	0·366653	0·367439	0·368224
1·62	0·369009	0·369797	0·370585	0·371374	0·372162	0·372950	0·373738	0·374526	0·375315	0·376103
1·63	0·376891	0·377682	0·378473	0·379265	0·380056	0·380847	0·381638	0·382429	0·383221	0·384012
1·64	0·384803	0·385597	0·386391	0·387185	0·387979	0·388773	0·389567	0·390361	0·391155	0·391949
1·65	0·392743	0·393540	0·394337	0·395133	0·395930	0·396727	0·397524	0·398321	0·399117	0·399914
1·66	0·400711	0·401510	0·402310	0·403109	0·403909	0·404708	0·405508	0·406307	0·407107	0·407906
1·67	0·408706	0·409508	0·410311	0·411113	0·411915	0·412717	0·413520	0·414322	0·415124	0·415927
1·68	0·416729	0·417534	0·418339	0·419143	0·419948	0·420753	0·421558	0·422363	0·423167	0·423972
1·69	0·424777	0·425584	0·426392	0·427199	0·428007	0·428814	0·429621	0·430429	0·431236	0·432044
1·70	0·432851	0·433661	0·434471	0·435281	0·436091	0·436901	0·437711	0·438521	0·439331	0·440141
1·71	0·440951	0·441763	0·442576	0·443388	0·444201	0·445013	0·445825	0·446638	0·447450	0·448263
1·72	0·449075	0·449890	0·450705	0·451519	0·452334	0·453149	0·453964	0·454779	0·455593	0·456408
1·73	0·457223	0·458040	0·458857	0·459675	0·460492	0·461309	0·462126	0·462943	0·463761	0·464578
1·74	0·465395	0·466214	0·467034	0·467853	0·468673	0·469492	0·470312	0·471131	0·471951	0·472770
1·75	0·473590	0·474412	0·475234	0·476055	0·476877	0·477699	0·478521	0·479343	0·480164	0·480986
1·76	0·481808	0·482632	0·483456	0·484280	0·485104	0·485928	0·486752	0·487576	0·488400	0·489224
1·77	0·490048	0·490874	0·491700	0·492527	0·493353	0·494179	0·495005	0·495831	0·496658	0·497484
1·78	0·498310	0·499138	0·499967	0·500795	0·501623	0·502451	0·503280	0·504108	0·504936	0·505765
1·79	0·506593	0·507423	0·508254	0·509084	0·509915	0·510745	0·511576	0·512406	0·513237	0·514067
1·80	0·514898	0·515730	0·516563	0·517395	0·518228	0·519060	0·519893	0·520725	0·521558	0·522390
1·81	0·523223	0·524057	0·524892	0·525726	0·526561	0·527395	0·528230	0·529064	0·529899	0·530733
1·82	0·531568	0·532404	0·533241	0·534077	0·534914	0·535750	0·536587	0·537423	0·538266	0·539096
1·83	0·539933	0·540771	0·541610	0·542448	0·543287	0·544125	0·544964	0·545802	0·546641	0·547489
1·84	0·548318	0·549158	0·549999	0·550839	0·551679	0·552519	0·553360	0·554200	0·555040	0·555881
1·85	0·556721	0·557563	0·558406	0·559248	0·560090	0·560932	0·561775	0·562617	0·563459	0·564302
1·86	0·565144	0·565988	0·566832	0·567676	0·568520	0·569364	0·570209	0·571053	0·571897	0·572741
1·87	0·573585	0·574431	0·575277	0·576123	0·576969	0·577814	0·578660	0·579506	0·580352	0·571198
1·88	0·582044	0·582892	0·583739	0·584587	0·585435	0·586282	0·587130	0·587978	0·588826	0·589673
1·89	0·590521	0·591370	0·592220	0·593069	0·593919	0·594768	0·595617	0·596467	0·597316	0·598166
1·90	0·599015	0·599866	0·600717	0·601569	0·602420	0·603271	0·604122	0·604973	0·605825	0·606676
1·91	0·607527	0·608380	0·609233	0·610085	0·610938	0·611791	0·612644	0·613497	0·614349	0·615202
1·92	0·616055	0·616909	0·617764	0·618618	0·619473	0·620327	0·621181	0·622036	0·622890	0·623745
1·93	0·624599	0·625455	0·626311	0·627168	0·628024	0·628880	0·629736	0·630592	0·631449	0·632305
1·94	0·633161	0·634019	0·634876	0·635734	0·636592	0·637449	0·638307	0·639165	0·640023	0·640880
1·95	0·641738	0·642597	0·643457	0·644316	0·645175	0·646034	0·646894	0·647753	0·648612	0·649472
1·96	0·650331	0·651192	0·652053	0·652913	0·653774	0·654635	0·655496	0·656357	0·657217	0·658078
1·97	0·658939	0·659801	0·660664	0·661526	0·662388	0·663250	0·664113	0·664975	0·665837	0·666700
1·98	0·667562	0·668426	0·669290	0·670153	0·671017	0·671881	0·672745	0·673609	0·674472	0·675336
1·99	0·676200	0·677065	0·677931	0·678796	0·679661	0·680526	0·681392	0·682257	0·683122	0·683988
2·00	0·684853									

FRICTION LOCATION ON SHAFTS

Taper bushes are widely used in numerous fields of industry for location on shafts. This article discusses some of their commoner applications and suggests how they may be employed for other purposes

by D. DENMAN*

THE principle of location by the use of tapered components has been known and used for many years in connection with taper keys, cotter pins and ball-bearing adaptor sleeves.

The wide-scale use of taper bushes for location on shafts, however, is a much more recent development. It is only within the last ten years that the use of taper bushes for the location of products such as V-pulleys, chain sprockets and couplings has become well established, and the use of taper bushes has enabled manufacturers of those products to offer correct bore size from a reasonably small stock where previously either a very large stock had to be carried or delay was caused in boring out to size. The fact that one particular bush can be offered with 20 different inch-size bores and 17 metric-size bores for use with one particular product gives some indication of the range possible.

The small additional cost of a product using a taper bush can usually be justified by greatly reduced assembly costs and cost of manufacture of the mating components. Whereas the mounting of a through-bore V-pulley can entail accurate machining of the shaft and the time of a skilled man fitting a taper key, the taper bush pulley can be fitted much more quickly by unskilled labour on a shaft of appreciably wider tolerances. Although the shaft tolerance is dependent on bush size and bore, an average tolerance of shaft which can be accommodated is +0·002 and −0·005 in.

The concentricity and degree of run-out on products fitted on a shaft by means of a taper bush are a definite improvement on those using a taper key for location and are comparable with those using a shrunk-on fit.

There is a limit to the size of product which can reasonably be offered "off the shelf" because of turnover compared with capital outlay. This has resulted in the sizes of bush under large-scale production being limited to those accepting shafts up to about 4¼ in. diameter. However, where the technical advantages rather than the commercial advantages warrant it, bushes with much larger bores are a practical proposition.

Several designs of taper bush have been used with varying degrees of success, but the basic principle of all such bushes is the same. Screws are used to exert an axial force on the wedge section of the bush and the resultant radial force locks the product on the shaft. The angle of taper is within the angle of friction, and consequently a force is

Fig. 1. Taper bush.

Fig. 2. Graph of slip torque against wrench torque for taper bush.

Fig. 3. Taper lock adaptor.

Fig. 4. Weld-on hub.

Fig. 5. Patented variable-speed pulley.

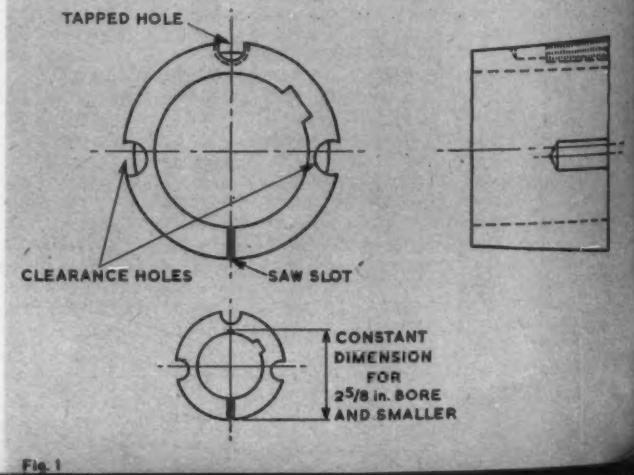


Fig. 1

* *Applications engineer, J. H. Fenner & Co. Ltd.*

required in the opposite direction to free the bush.

Fig. 1 illustrates a patented taper bush using this principle; 25,000 of this type are produced every week. Tapped half-holes in the boss take screws which bear on to the bottom of clearance half-holes in the bush, providing the force necessary to lock the bush in position. When the bush needs to be released, the two jacking-on screws are removed and one of them is used in the jacking-off hole (bush half-hole screwed and boss blind half-hole clearance) to remove the bush. For large-diameter bushes three jacking-on screws and two jacking-off screws are used. In the design of bush shown, grub screws are used to provide a flush face on the boss when assembled; this is a definite safety feature. The split in the bush is required to make the necessary deformation possible and, as shown in the diagram, the split is continued through the keyway for the smaller bores, the distance between the end of the slot and the outside of the bush remaining constant.

Using a wrench torque within the limits imposed by the screw manufacturers, a grip is obtained which will transmit sufficient torque for most applications. However, a keyway is provided in this type of bush for more severe conditions, such as where excessive vibration is encountered, or where there is a large cyclical variation in torque. When a key is used, it must have top clearance, as a top-fitting key restricts the slight deformation of the bush which is essential to satisfactory performance. The fitting of a key without top clearance will invariably result in the bush fracturing along the keyway and the resulting localised stress can cause the boss of the housing to fracture. Another method of obtaining greater torque-transmitting capacity is to drift the bush. The method employed is to tighten the bush by means of the screws using a normal wrench torque and then to tap the bush farther in. It is then possible to tighten the screws farther and this procedure can be repeated.

Fig. 2 shows a graph of slip torque against wrench torque applied to the screws for three sizes of bore of one size of taper bush; the horizontal part of the curves show the ranges of slip torque available with drifting.

It can be seen that the larger the bore, the greater the torque when slipping will occur. This is caused not only by the fact that the friction is applied at a greater radius, but also that the larger bores result in a smaller wall thickness of the bush to be deformed.

Using a 5-h.p. 1,500-r.p.m. synchronous speed motor of frame size to B.S. 2960: 1958, the shaft diameter is 1⅛ in. A V-belt drive used to transmit power from this motor to a fan at 1,535 r.p.m. using normal service factors would be 5 in. o.d. × 3A to 4¾ in o.d. × 3A. The slip torque of a bush suitable for the motor pulley, using normal wrench torque, would be 275 lb./ft., and for the fan pulley (1½-in.-shaft) 335 lb./ft. These slip torques give safety factors of 15·3 and 19·5 and if the motor were used with direct on-line start giving a starting torque of approximately twice full-load torque, these safety factors would be reduced on start to 7·6 and 9·7.

The method of location without the use of keys lends itself to the accurate positioning of products on shafts not only axially but also angularly. A recent application in which this was used to advantage was where a double-ended motor direct-coupled to two alternators by means of flexible couplings was to be used in an experimental laboratory. The phasing of the two alternators relative to each other had to be varied and this was obtained by means of taper bush location of the coupling halves.

The tooling costs for economic production of products with taper bores having clearance half-holes and tapped half-holes is quite substantial, and although the bush manufacturer will normally taper bore small batches of customers' own products, another method of taper location was required for one-off jobs. This has been accomplished in two ways, one of which is by the use of a taper bore adaptor (see Fig. 3). This adaptor, used with products having bosses, has a radial split which allows it to expand in the bore of a product and provide a grip approximately equal to that of the bush on the shaft.

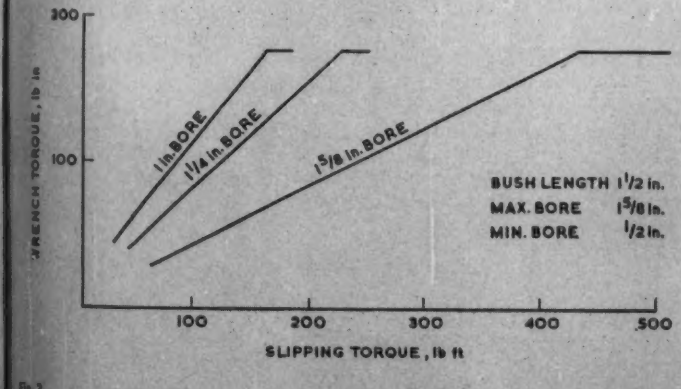


Fig. 2

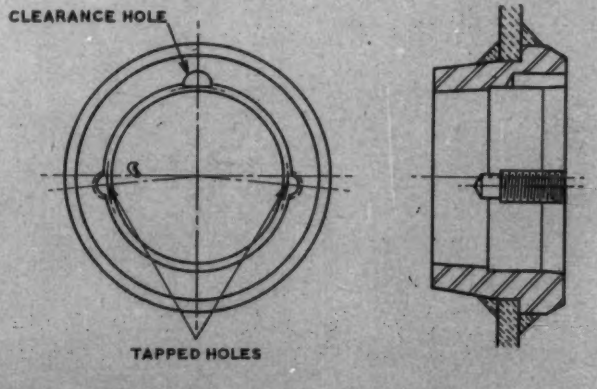
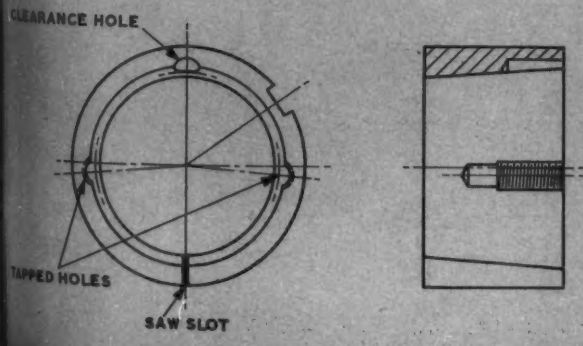


Fig. 4



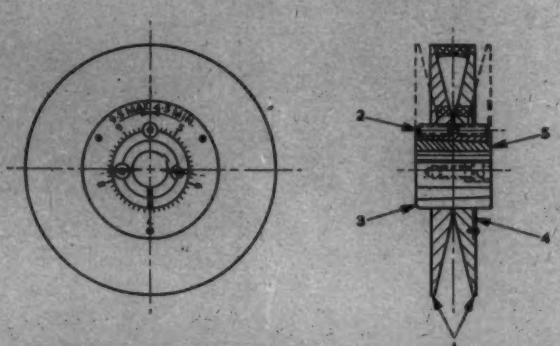


Fig. 5

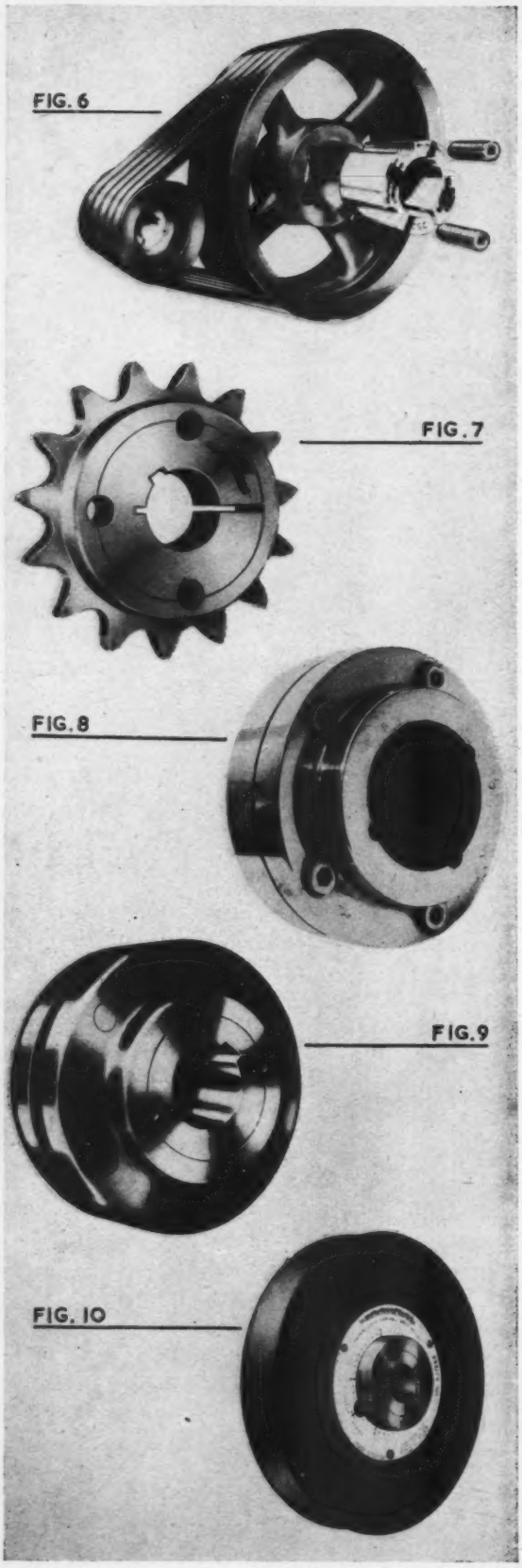


Fig. 6. V-belt drive comprising driving pulley, driven pulley and belts, with exploded view of taper lock bush.

Fig. 7. Taper lock chain sprocket.

Fig. 8. Taper lock rigid coupling.

Fig. 9. Taper lock disc-type flexible coupling.

Fig. 10. Hainsworth 993/2Q stationary adjustable variable-speed pulley.

The force required to bend the adaptor sufficiently to take up clearances reduces the force on the bore of the product, but this is balanced by the fact that the force is acting at a bigger radius than the force on the shaft. From practice it is found that the first part to slip is the bush on the shaft; therefore, the slip torque figures for the bush can still be used for purposes of calculation.

Taper bush adaptors offer all the advantages of taper bushes, and the advantage of concentricity mentioned in connection with taper-bored products still applies, although slight inaccuracies due to machining tolerances are increased due to the addition of one part.

Obviously the force applied to the shaft has a reaction which causes a bursting stress in the boss holding the adaptor. The adaptor manufacturer imposes a minimum limit on the diameter of boss which varies according to material.

These adaptors are normally used for ease in assembly or where it is undesirable to cut a keyway in the shaft and consequently have been specified in original design, but they have also proved useful in repair work. Where a damaged bore would otherwise have meant the scrapping of a component, the bore has been opened out to receive an adaptor. On occasion, mild-steel straps have been shrunk on to the boss when the boss diameter has been below the recommended minimum.

The other method of providing a taper bore, for use with fabricated components, is to use a mild-steel taper-bored hub as in Fig. 4. This is designed for welding on to a web, shown dotted. These have been used successfully on tumbling barrels, the rotors of fans and stirrers of mixing vessels, but their most popular use is on conveyor pulleys. In this latter case, and any other application where two weld-on hubs are used to locate on a shaft, the hubs should be assembled with the taper bushes on a shaft for welding to ensure correct alignment. The cavity in the bore is used in the larger sizes of weld-on hub to minimise the distortion caused by welding.

A product using all the advantages offered by the use of a taper bush is the variable-speed pulley shown in Fig. 5. This pulley is for use with a V-section belt in conjunction with a pulley of fixed diameter and offers an infinite speed variation of 2·1 : 1 ratio. The pulley is for use where speed changes can be effected when the drive is stationary, and the taper bush principle of location by locking all the parts overcomes the problem of fretting corrosion which is met with in most designs of variable speed pulley. When the pulley is loose on the shaft, the two cones (1) can be moved by means of the right- and left-hand threaded screw (2) from the position shown in full, where the belt is at its maximum pitch circle diameter, to the position shown dotted, where the belt is at its minimum pitch circle diameter. A scroll on the outside of the split hub (3) used in conjunction with the cover plate (4) indicates the pitch circle diameter which the belt assumes for any position of the cones, and this enables the drive to be set to give a predetermined driven speed. The taper bush (5) is used to lock itself to the shaft and also to expand the hub sufficiently to lock the cones.

DESIGN OF HIGH DUTY IRON CASTINGS

This article broadly discusses the technique employed to produce high-duty iron castings, and puts forward some practical suggestions for designing them so as to reduce costs or exploit their properties more effectively

by E. G. DONALDSON, B.Sc.*

IN designing a casting, the engineer is not only concerned with function and service but should be able to view his drawings through the eyes of the pattern maker, the core maker, the moulder, the fettler and the machinist in order that the result should be intrinsically and economically successful.

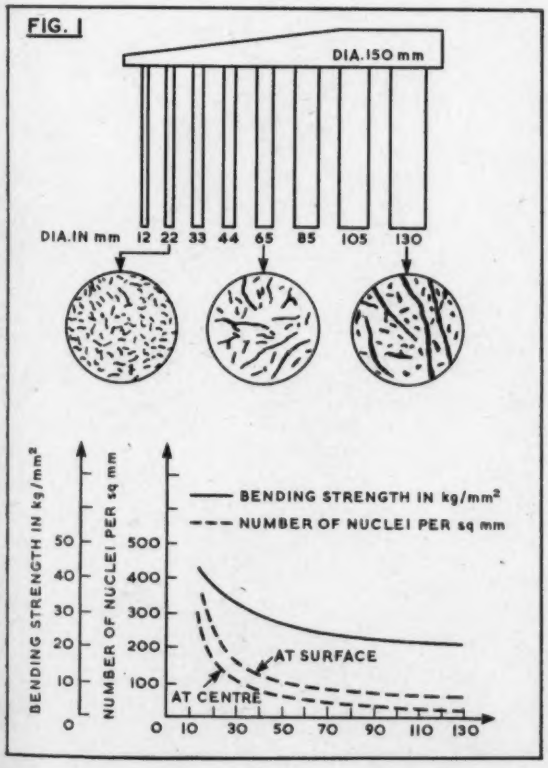


FIG. 1
DIA.150 mm
DIA.IN mm 12 22 33 44 65 85 105 130
BENDING STRENGTH IN kg/mm²
NUMBER OF NUCLEI PER sq mm
BENDING STRENGTH IN kg/mm²
NUMBER OF NUCLEI PER sq mm
AT SURFACE
AT CENTRE
0 10 30 50 70 90 110 130

Fig. 1. Influence of section thickness and cooling rate on the size and number of graphite flakes and on bending strength.

Metallurgically, designers are often not exact enough. They are generally aware that several grades of cast iron exist, but the exact physical specifications required are rarely attached to the drawing. Such terms as "cast iron", "close-grained iron" or "material to B.S.", without reference to the particular grade required, are commonplace, but this information is insufficient for the foundry, where the purpose of the part or the strength properties needed are often not known.

Because each grade has its own running and solidification characteristics, the type of metal used has an influence on the casting design. To obtain a sound casting, the rate of cooling and solidification should be as uniform as possible over the whole casting. Sharp angles giving rise to hot spots, porosity and planes of weakness should be avoided.

The factor of safety applied will also be affected by the material. Where a safety factor of 3 might be regarded as suitable for steel, a factor of 8 would probably be considered necessary for cast iron and a factor of 5 for a high-duty cast iron such as Meehanite would be satisfactory.

The foundry manager often can spot factors which would reduce cost, enable sounder castings to be produced and lower the scrap rate; but as quotations have probably been requested from his competitors and a dateline is specified, he is usually in no position to question the design and try to obtain modifications. The necessary co-operation between designer and foundry should start at an early stage in the development and certainly before the inquiry stage.

All grades of cast iron contract during solidification and cooling. The thinner sections solidify first and the thickest sections last. This results in the production of coarser structures in the thicker parts, and, in grey iron in particular, the production of coarse graphite. This coarse structure has lower physical and mechanical properties, i.e., lower harness and tensile figures (see Fig. 1). This phenomenon applies to all grades of grey iron (see Fig. 2), but the use of an inoculated high-duty iron produced by careful metallurgical methods mitigates this trouble to a great extent (see Fig. 3). A close-grained material with finely-dispersed graphite is desirable for engineering purposes.

However, due to the critical change points, one part of the casting may be expanding while the other is contracting

* *International Meehanite Metal Co. Ltd.*

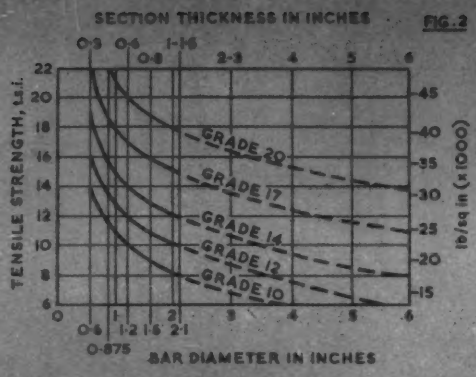


Fig. 2. Section sensitivity of cast iron, measured by variation of tensile with tension. (Grades according to B.S. 1452.)

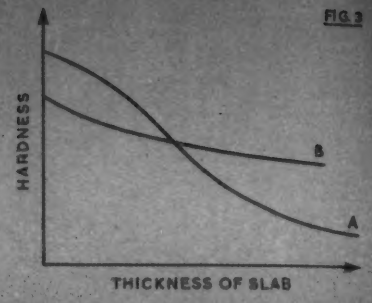


Fig. 3. Section sensitivity, measured by variations of hardness with section, for ordinary cast iron (A) and high-duty iron (B).

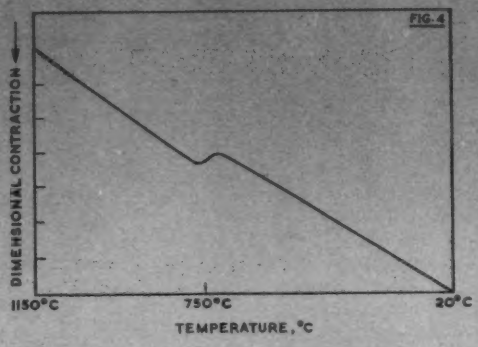


Fig. 4. Typical cooling curve of Meehanite metal or steel after solidification, showing contraction and expansion with temperature fall. Note the expansion that occurs at about 750 deg. C. during the austenitic pearlite inversion, which is followed by contraction to room temperature.

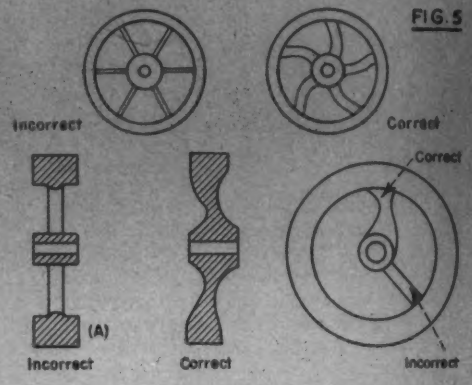


Fig. 5. Casting strain may be avoided by having spokes of sufficient section to have a cooling rate similar to the hub and rim.

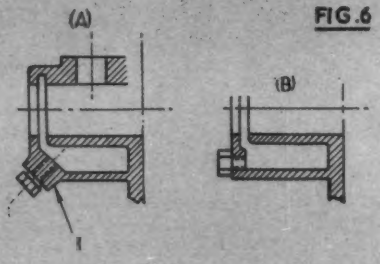


Fig. 6. Boss (A) is incorrect, (B) is correct. Note that a loose pattern piece is necessary.

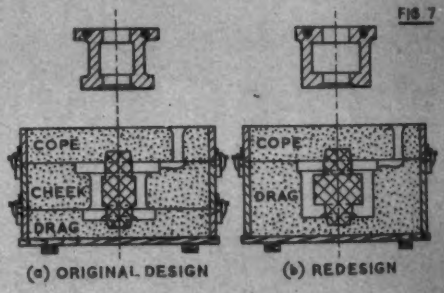


Fig. 7. Redesign to change mould production from a three-part mould to a two-part mould.

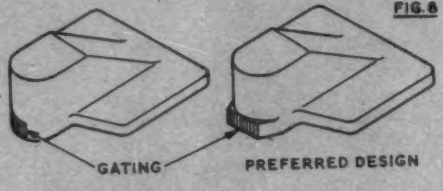


Fig. 8. Design with flat area is easier to gate and clean.

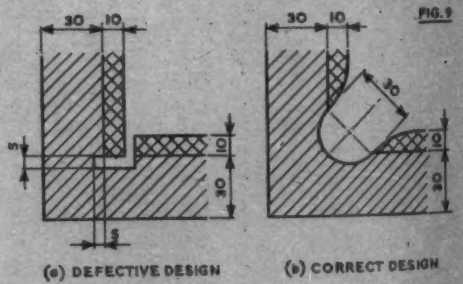


Fig. 9. Design for tool clearance.

Fig. 10. Location points (A) for machining.

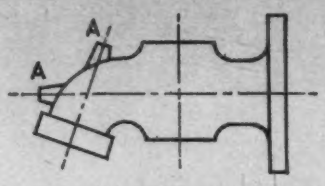
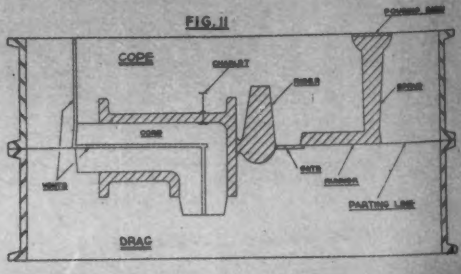


Fig. 11. This ideal set-up in sand will produce minimum scrap.



(see Fig. 4). Contraction on cooling sets up stresses which, if allowed to develop, will cause the part to crack, either in the mould prior to knock-out, or in many cases at a later stage. Cracking may occur during machining operations or even while in service. The effective strength of a casting is the intrinsic strength of the material used, less the internal stresses set up during the solidification and cooling stages. Thus, high casting stresses may well result in very low effective strength in the casting. A major factor in causing stresses in a casting is a wide variation in section thickness. Thus it is advisable to adopt the rule that the ratio of maximum to minimum sections in a casting should never exceed a ratio of 2½-3 : 1.

Reducing Casting Stresses

The following are recommended modifications that will help to ensure that the contraction stresses do not exceed the tensile stress of the metal and thus crack the casting.

1. The evening up of all the sections to allow uniform cooling.
2. The substitution of an odd number of spokes in a wheel or pulley for an even number to prevent the stress concentrations being equal and opposite.
3. The substitution of bent spokes for the straight spokes, so that instead of stresses cracking the spokes they merely straighten slightly.
4. The avoidance of re-entrant angles.
5. The use of fillets.

The classic case of design modification for ensuring uniform cooling is the pulley wheel shown in Fig. 5. The original design in this could probably be cast in a low-tensile open-grain type of cast iron where the contraction on solidification and cooling is of quite a low order. However, when casting high-duty iron which has a much higher rate of contraction it is essential that the modified design be adopted. This fact is often brought to light when an old pattern is taken out again fro mthe pattern store for the casting of a replacement part. The foundry find that, due to their melting a much higher strength iron than in the past, the resultant casting has cracked in the mould during cooling and only with modification to the design can they produce a sound casting.

The rim of the flywheel (shown at A) is designed heavier than the spokes and, when poured, solidifies last. Due to restrained contraction and cooling of the uneven sections, the rim will be left with tension strains, with corresponding compression forces in the spokes and hub. Arms of sufficient section, having a cooling rate more nearly that of the rim and hub, represent good design.

Designing for Minimum Cost

The pricing of a job will usually be based on direct labour costs such as core making, moulding and fettling, plus the metal cost, plus a percentage to cover overheads and profit. The direct labour costs will usually exceed those of the actual cost of the metal. The estimated weight and the labour costs are calculated from the drawing and the price is then conveniently expressed in the quotation in terms of pounds sterling per ton or per piece. Thus, the actual weight of the casting may be of secondary importance and the major items in the costs will be for moulding, core making and fettling. In many cases, a minor change in design can produce a big reduction of labour costs in making the casting. Even more important is that it may considerably reduce the chances of making defective castings. Again pattern-making costs will be a predominant factor when the order is for only one casting. When the order is for thousands off, then the pattern costs will assume a position of small importance. But frequently a modification in pattern design will allow labour costs to be reduced and at the same time enable better castings to be obtained.

For example, if cores and loose pieces (Fig. 6) can be eliminated, then pattern making, core making and moulding times can be reduced. If bad lifts by the moulders can be avoided by the simple expedient of increasing the taper, especially on cods (the raised portions of the mould), then moulding costs will be reduced. If two box parts can be used instead of three by a simple modification in design, again a saving is achieved (see Fig. 7).

The knock-out and fettling time can be reduced by allowing for easy knock-out of the cores and by the situation of feeders on thick sections where break-off is good and breaking-in is unlikely. The use of multiple coring with the resulting incidence of internal flash will also increase the dressing-shop time. The placing of feeders and ingates in such positions that stand and swing frame grinders cannot be used and hard grinders must be resorted to will similarly increase the casting cost (see Fig. 8).

All these facts must be considered by the designer, and consultation with the foundry may save considerable cost.

Designing Castings for the Machine Shop

The question of machining allowances is important, but only the founder can judge whether his metal melting, moulding and coring methods can economically attain the limits specified in the drawing.

Although on average the machining of a casting costs twice that of the casting itself, there are limits to the reduction of machining allowances. If the designer specifies extremely small tolerances on the casting, then he may find that machine-shop rejects will be high and the ultimate cost of the job increased. Where little or no machining is an essential condition, then he may have to resort to precision moulding. The cost per piece in that case will be extremely high by comparison with the ordinary sand foundry and this can be justified only in certain very special cases.

It should be the object of the designer to present a casting to the machine shop which requires the minimum of machining. More important still, all surfaces to be machined should be readily accessible (Fig. 9) so that the machining can be of the simplest and cheapest form; e.g., capstan lathe rather than milling machine. The general shape should facilitate the identification of location points (Fig. 10) so that setting-up time is reduced to a minimum and holding difficulties eliminated.

Although the first general rules for casting design were published in 1926, it is only in the last few years that suitable reference books on the subject have been published. Obtaining the ideal set-up (as in Fig. 11) may not be possible with every job, but the foundryman's advice at an early stage in design development may save much trouble.

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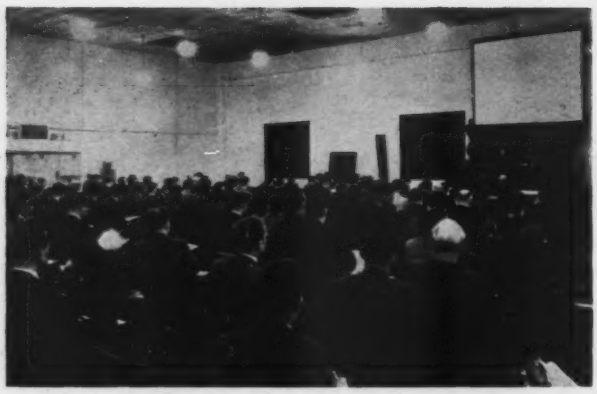


A view of the conference hall during one of the technical sessions.

DESIGN ENGINEERS IN LONDON FOR EXHIBITION AND CONFERENCE

More than fifteen thousand people visited the Engineering Materials and Design Exhibition held at Earls Court during February

LONDON recently saw the greatest concentration of design engineers ever assembled anywhere. The occasion? They came—by the thousand—to see and take part in the first Engineering Materials and Design Conference and Exhibition, representing almost every branch of industry in Britain, as well as many overseas countries: New Zealand, Australia, the U.S.A., the U.S.S.R., Germany, Switzerland, China, Japan, Austria, France, the Netherlands and Sweden.

The conference alone attracted more than 2,000 delegates and their colleagues. Through a special facility for tickets to be transferable between members of individual firms, many organisations were represented by different members of their staff at each session, thus enabling specialists to derive most benefit from the talks.

Dr. Barnes N. Wallis, chief of research and development of Vickers-Armstrongs (Aircraft) Ltd., who officially opened the proceedings, described it as a unique exhibition, "in that it is intended to bring designers into direct contact with all the new materials which are available, and you will, if you are yourselves designers as well as engineers, realise how profoundly designs may be affected by knowing that certain new materials are available. I could give you a number of instances in our latest developments of variable wing aircraft; in fact, I think the ability to make the wing of an aircraft swing in azimuth through an angle of nearly 90 deg. really depends upon the use of one of the latest anti-frictional plastics, p.t.f.e., about which you will be learning in the course of the conference."

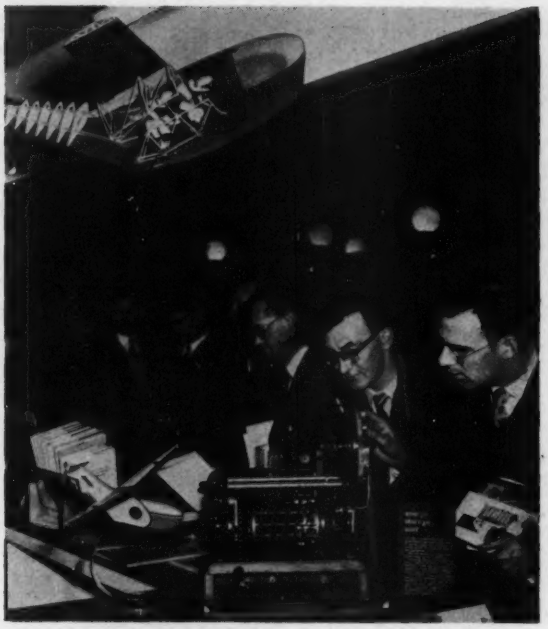
Discussing the series of twenty technical papers that were to be delivered during the days following, Dr. Wallis referred to one dealing with appearance design, and said: "All designers go through those two trying stages which the author describes as perspiration and inspiration, but I would add one more to the list of requirements, that is, an intense conviction on the part of the designer that something requires to be done.

"How these convictions arise is, no doubt, a complex matter. Heredity, early training, schooldays, the conversation of those about us, our early technical training, all these things combine to produce some state in our minds, which gives us a clear conviction amounting almost to an obsession sometimes, that the world stands in need of something new, some step forward in the way of technique and design, or application of materials to some well defined and special purpose.

"Perhaps the most general statement which I have been able to come across in this series of excellent papers* is that in the closing paragraph of Mr. Nieboer's paper. He concludes by saying: 'The "post-engineering" world has replaced the human being as a power source by energy derived from water, coal, oil, atoms, etc. In order that this power and the goods that it makes possible be of lasting benefit to society, it must provide maximum satisfaction for

Dr. Barnes N. Wallis, who opened the conference and exhibition, explains an amusing point of detail to Mr. V. A. Kamensky, head of the U.S.S.R. trade delegation in the U.K.

What makes the wheels go round? Many visitors were puzzled by this mechanism on the E.M.D. stand. Some guessed, others wandered off muttering about eddy currents. No prizes offered for the correct answer.



Another mechanism to catch the eye of the passer-by. This was an energy storage unit, a scaled-down version of the equipment designed for the "fly-cycle"—tomorrow's answer to the traffic jam.

a maximum number of people in a minimum of time for a minimum effort.'"

Many Visit Exhibition

Greater-than-usual interest was reported by many exhibitors who were kept busy with a lively flow of technical inquiries; visitors, too, admitted their satisfaction at finding on the stands representatives who were receptive to the many design problems that were discussed. One visitor, for example, said that in three hours at the exhibition he had been able to obtain technical information for a project which would have taken at least three days by any other means.

Exhibits at the show fell broadly into three main groups. Traditional materials and production methods were in evidence, but there was a strong emphasis on more recently-exploited materials and techniques, such as beryllium, stainless steels, a variety of plastics, compressed wood fibre, reinforced glass, precious and semi-precious metals, sintered metals, ceramics and light alloys. Among the components to be seen were gears, bearings, couplings, filters and seals.

More than 15,600 people visited the exhibition, which was held at Earls Court.

*** Supplies of the preprinted papers, which were issued to all registered delegates, are now exhausted. It is planned to publish a complete set of all papers read at the conference, together with a record of the subsequent discussion that took place. These are expected to be made available at an approximate cost of two guineas. Orders may be placed now.**

Did you enter this guess-the-weight competition? The secret was in first identifying the metal: steel, aluminium, chromium-plated wood? Hollow or solid? See page 204 for all the answers and all the winners.

Crowds of visitors who came to Earls Court took a keen interest in the exhibits, and manufacturers' staff reported a lively flow of inquiries. This picture was taken towards the rear of the exhibition area.

ATOMIC HYDROGEN WELDING

The atomic hydrogen welding process has useful applications for facing, and rebuilding a wide range of cutting tools. This article describes the technique and its advantages over other welding methods

by ERIC N. SIMONS

WELDING with the aid of atomic hydrogen is a process of the type known as shielded arc. In this, oxidation and nitriding are prevented by the enclosure of the weld in an envelope of gas, in this instance hydrogen. The arc is formed and controlled between a pair of tungsten electrodes, and the welding is done either manually or automatically. It should be noted that atomic hydrogen welding is different from arc welding in that it requires a much higher voltage (up to 100 volts on occasion).

The apparatus required comprises a power control unit, electrode holder, devices for stopping and starting (usually buttons) and the cables for providing electric current and hydrogen gas. The holder for the electrodes is made up of two tubes, one for power, the other for gas. Each tube has a handle at one end made of an insulant, and by way of this, the gas and the power pass from the connection. The opposite ends of the tubes are provided with a fixture for gripping securely the tungsten electrodes.

In this manner the electrodes are held at an angle of about 30 deg. to each other, and the fixtures also carry the holes by way of which the gas is introduced. The proximity of the electrode tips causes the arc to form. One of the two tubes has a flexible loop connected to a trigger on the handle. The welding torch being held in the right hand, a light pressure with the forefinger on the trigger causes the electrodes to move away from each other. On release of the pressure, the electrodes return to their original position. In this way arc length and electrode distance are easily regulated.

The atomic hydrogen process uses the heat or energy of the arc to atomise the surrounding envelope of hydrogen gas, and this is an effect enhanced by the presence of the tungsten electrodes. The atomisation of the gas is accompanied by an absorption of energy from the arc, which energy is liberated when recombination into molecules takes place. The result is intense heat, causing the weld surfaces to fuse. It will be seen, therefore, that the heat energy is derived solely from the power, the gas being merely a carrier.

The welding arc has an unusual shape. With elongation of the arc, the loop, shown in Fig. 1, expands. When the arc is shortened, it contracts. The length of the arc ranges from $\frac{1}{4}$ in. to 1 in., and as welding proceeds a characteristic hum or buzz is heard. The welding metal is provided by a filler rod of the composition desired. With the torch in the right hand and the rod in the left, welding proceeds as in oxy-acetylene blowpipe welding.

If the arc is of the correct length, it produces a long and constricted source of heat. The arc flame is termed a "fan" and is maintained in a vertical position, nearly parallel to the line of the weld. So placed, it heats an area about four times as long as wide, so that by this process exceptionally narrow welds can be produced. Where particularly wide welds are necessary, the fan is traversed slowly from one side to the other and back. For narrow welds and where the material being welded is thin, it is better to keep the fan steady. The special form of the arc has the advantage that it gives a temperature gradient. In other words, the exterior preheating zone of the flame preheats the weld surface. The inner zone provides and produces the proper welding heat. The exterior stress-relieving zone, as the fan leaves the zone at the proper temperature, prevents too rapid cooling, allowing trapped gas to escape before the metal has solidified and providing a relief of stresses, so that the material is not embrittled.

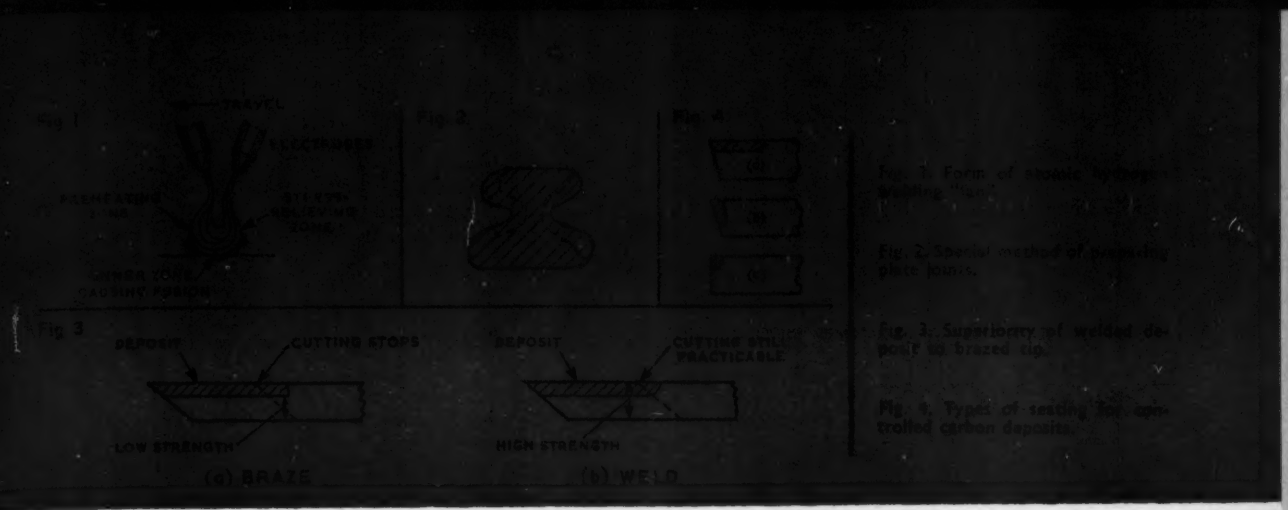
The gaseous envelope within which the arc operates excludes oxygen and so prevents air from causing oxidation of the weld metal. Welds made by atomic hydrogen welding are free from oxidation and slag inclusions, have a uniform structure, are ductile and well finished, with surfaces unspoiled by patches of oxide, or metallic splashes resulting from turbulence in the weld pool. In consequence, less time and money are spent in finishing by grinding and other processes.

It will be seen that the atomic hydrogen process is excellent for long runs, and can be used for almost every type of metal or alloy. It is flexible and easy to operate, and because the cool outer portion of the gas envelope is not too severe in its quenching effect on the hot metal, it prevents the formation of cracks and gasholes. The underside of the weld is less scaly, and it becomes possible to do away with backing bars or plates when welding automatically. The deposits made by this process are, therefore, of maximum purity.

Automatic welding can be used for this process, especially in the welding of tubes and cylinders having longitudinal seams or seams of circumferential type. The mechanical principles involved are largely identical with those of other machines for automatic welding, including provision in the latest types for electronic control. Both

TABLE 1. Characteristic welding rates for low-carbon steel plate

Plate Thickness in.	Approximate Welding Rate in./min.
$\frac{1}{16}$	10
$\frac{1}{8}$	6
$\frac{3}{16}$	5
$\frac{1}{4}$	4·5
$\frac{5}{16}$	3·75
$\frac{3}{8}$	3
$\frac{7}{16}$	2
$\frac{1}{2}$	1·2



single- and multiple-arc machines are manufactured, the multiple-arc machines being used for greater production or heavier deposits. There is, nevertheless, a limit to the practicable increase of amperage in a single arc.

In some of the most modern machines for multiple-arc welding by atomic hydrogen, the arcs are electronically controlled so that they move closer to or farther from the work as the melting rate of the electrode metal varies. Some arcs are closer to each other than the rest. The closest are the first set designed for preheating. The others are wider apart according to whether they melt the metal, maintain the weld temperature, or serve as shields from too rapid cooling by the air.

Automatic welding of tubes in such machines consists of feeding metal blanks into a milling roll and bevelling their edges, so that when brought together for welding they form a weld vee with a gap of about $\frac{3}{32}$ in. at the bottom. As the tube moves forward for welding, the flanks are pressed to bring the edges closer together at the gap. The first set of arcs preheats; metal is then put down and gathers at the root of the vee. The intense heat softens the edges of the seam so that lateral pressure narrows the vee still further and only a small amount of metal is needed to close it.

Closure of the vee in this way effected, the weld metal is kept hot so that the unfused layers of metal below the weld pool take up heat and become plastic enough for steady pressure to forge-weld the base of the vee and thicken the tube wall at this point. The welded tube now passes to the more widely-separated arcs, which provide just enough heat to keep the weld surface liquid, yet allowing the metal to solidify from the root of the vee upwards. Trapped gas is given time to escape. The tube slowly loses heat and plasticity as it progresses, and stresses are liberated and relieved, so preventing cracks from being caused. Final rolling gives uniform wall thickness.

Short pieces of metal are sometimes inserted in the joint in automatic welding. For butt welding these are somewhat larger than the gap to be filled. They make up for irregularity in the preparation of the edges and render the seam slightly stronger. Corner butt welding is done by melting a rod of the proper diameter in the joint to be welded.

Plates $\frac{1}{16}$ in. thick and under can be butt-welded without chamfering the edges. Plates over $\frac{1}{4}$ in. thick must be welded at top and bottom, giving their edges a double vee, having an included angle of 80-90 deg. Thicker plates than this need a special type of joint preparation, as shown in Fig. 2. Filler rods must be used for corner welds, and only thin material should be welded with no addition of filler metal.

The intense heat of the atomic hydrogen "fan" enables high-speed welding to be carried out. Butt- or fillet-welding of $\frac{1}{4}$-in.-thick plates with low-carbon steel can be welded by deposition at the rate of 1·2 in./min. Plate $\frac{1}{8}$ in. thick can be welded at 6 in./min. Electrode size is usually suggested by the machine manufacturers. Electrode consumption depends largely on gas consumption and purity.

The applications of atomic hydrogen welding correspond largely to those of oxy-acetylene welding, but of recent years these have been extended by the discovery of a method of controlling the carbon content of the weld metal. Hydrogen, it should be noted, extracts a considerable amount of carbon from the metal of the filler rod. Since carbon is the hardening element in steels, this is liable to produce, and does produce, a marked deterioration in the hardness of the weld metal. In some instances as much as 50 per cent of the carbon in a weld may be lost, so that the weld metal has different physical properties from the parent metal. In a number of applications this loss of carbon is sufficient to render the part unsuitable for its function after being welded. Some of the lost carbon may be compensated for by pick-up of tungsten, itself an extremely hardening element, from the electrodes; but usually it becomes necessary to increase the carbon content of the filler rod. Sometimes these rods have twice as much carbon as the parent metal.

Steels with a carbon content higher than that of mild steel need from one-fifth to one-third more carbon in the rod than in the parent metal. Alloy steels can be welded by the atomic hydrogen process without extra carbon in the rod, as long as this has a composition corresponding to that of the parent metal. The higher carbon steels should be preheated to 400 deg. C. before welding, to prevent cracks. Gradual cooling after welding is also advisable.

The loss of carbon in welding by this process prevented it from being applied to high-speed steel and other steels where extreme hardness was desirable. For example, a filler rod with 0·75 per cent carbon gives a deposit of only 0·3-0·4 per cent carbon. Even a rod with 1·1-1·2 per cent carbon does not give the necessary 0·75 per cent carbon in the deposit. In fact, the greater the carbon content of the rod, the higher the proportion lost, so that the weld metal deposited remains almost the same. Carbon, remarkably enough, is apparently the only element which undergoes loss in passing from filler rod to weld.

The development of a British process in which filler rod and deposit for atomic hydrogen welding could be similar, or in which the deposit could be given high or low carbon as desired, made it possible for the first time to use the process for welds in which the deposited metal had to form a hard cutting edge or a hard surface for a wearing part. Moreover, the deposits so made could be forged, if necessary, and were purer and less porous, and freer from non-metallic inclusions, than welds previously made by this process.

The process is specially suitable for slender or fragile

tools likely to fracture in service when their blades are of solid high-speed steel. It is economical over a wide range of tools and allows the rebuilding of tools to the original size when worn. Tools are virtually free from base-line cracks, so that the method is much better than brazing. Fig. 3 shows why a weld made by the controlled carbon process of atomic hydrogen welding gives a stronger joint than brazing.

High alloy steels are readily welded, and deposit welds have been made with alloys containing 70-80 per cent tungsten, as well as other alloys. Complete control, both physical and metallurgical, is now made possible. There are three types of seating for tools so welded, as shown in Fig. 4. That shown at (a) is for tools to be resharpened on the front; (b) is for tools resharpened by grinding at the top; (c) is for tools to be reground in both directions; but in most instances (a) and (b) seatings will prove satisfactory.

Examples of applications for this controlled carbon process are the repair of gear cutters, single-point lathe or other cutting tools, the manufacture of special tools for parting-off large bars, etc., the tipping of boring bars and wood-working machine knives, the salvage of damaged tools made of costly steels and the manufacture of keyseating tools.

For the normal atomic hydrogen welding process, Table 1 below shows characteristic welding rates for different thicknesses of low-carbon steel plate. The essential components of the welding set from the electrical point of view are elec trode holder, transformer, reactor, tapping switch or other suitable arrangement for changing the current, push-button for stop and start, and ammeter. It is usual to embody an automatic hydrogen valve to ensure that the gas flows only when the current is switched on. Two different patterns are built up, namely, panel and truck. Of these, the truck type is the more compact.

SEEKING NEW SOURCES OF POWER

SOME recent studies at the Wright Air Development Centre in the U.S.A. have been devoted to the theory and practice of generating electrical power by means other than rotating machinery and conventional batteries; some results of this work have lately been published:

OSCILLATING GENERATOR—Two types of oscillating generator were studied: the moving-coil type with a permanent magnet field and the fixed-coil variable-reluctance type.

There is some advantage in using a fixed coil and varying the reluctance of the magnetic circuit in that, since the coil is stationary, more turns can be employed and the problem of stress on the coil turns is eliminated. In addition to the ever-present problem of leakage flux, the variable reluctance generator also has the problems of demagnetisation from coil current and no-load magnetic damping of the moving element.

THERMOPILE GENERATOR—In general, copper is a poor material for use in a power thermopile, since its high thermal conductivity overshadows its low electrical resistance, giving low efficiency.

Iron and constantan is a better combination for a power thermopile than copper and constantan. Although iron has a higher resistance than copper, its thermal conductivity is much less and its thermoelectric e.m.f. *vs.* constantan is higher. This results in a greater power output and higher efficiency for the same temperature differential. The iron-constantan thermopile, with the same number of junctions and temperature differential, delivered a maximum power output of 2·6 watts at an efficiency of 0·24 per cent. The no-load voltage output was 10 volts. It was found that copper cooling fins on the cold junctions, though small, were very effective in dissipating the heat from the junctions.

The greatest efficiency can be obtained from any given thermopile if a technique of construction is used so that the thermal insulation between elements is a minimum.

Thermocouples made of semiconductor materials have, in general, a higher internal resistance than those with metal elements; however, the e.m.f. can be much higher. There is reason to believe that, in analysing semi-conductor thermocouples, Boltzmann statistics should be used instead of Fermi-Dirac statistics used with metals. Favourable efficiencies could therefore be expected with some semiconductors as a result of their high thermoelectric power and because the high phonon conductivity is partly compensated by the fact that the electrons and holes follow Boltzmann statistics.

FUEL CELLS—Nearly all attempts to produce operating fuel cells have been empirical, because little is known about the chemistry, thermodynamics and reaction kinetics of substances at temperatures very far above room temperatures.

In order to establish with greater certainty just what direction future research in this field should take, an attempt has been made to evaluate each of the existing fuel cells that have been reported in the literature.

SOLAR CONVERTER CELL—Work in this area was directed principally toward the study and evaluation of the silicon p-n junction type of converter. A study was made of the basic action and analysis of the device, and data were obtained relative to the load characteristics of a commercially available cell. Overall obtainable efficiencies are said to be in the order of 6-15 per cent. The no-load voltage, with a solar illumination of around 10,000 foot-candles, is approximately 0·5 volt. The maximum power output, with this illumination, is in the order of 12 mW. The cell will withstand a great deal of shock and vibration and should have a long life.

NUCLEAR CONVERTER CELL—Nuclear converters may be classified as direct charging, contact potential, thermocouple, semi-conductor junction, and miscellaneous.

In the direct charging type, charged beta particles from a radioisotope source are collected on a conducting layer electrically insulated from the source. A voltage of 7,000 volts and a current of 40 $\mu\mu$ amps has been obtained. The obtainable voltages are limited by insulation leakage. The constant potential converter consists of two electrochemically dissimilar electrodes separated by a dense gas. The open-circuit potential is determined by the contact potential of the electrodes. Voltages of 1·1 to 1·9 volts, with current multiplication a hundred times that of the beta particles given off, have been reported. The semiconductor junction cell makes use of the properties of a p-n junction in a manner similar to that of a silicon solar cell except that the energy is given to the junction by radiation from a radioactive isotope. Voltages from 0·2 to 10,000 volts and currents of 5×10^{-12} to 5×10^{-6} amperes have been obtained. In the thermocouple type, radiation from a radioactive source causes the temperature of the thermocouple junction to rise. The efficiency of this type is seriously limited by the low efficiency of the thermocouple itself.

Nuclear converters, to date, are very low power devices and have very low efficiencies.

W.A.D.C. Technical Report, "Unconventional Electrical Power Sources", 54-409, Pt. 3.

designer's notebook

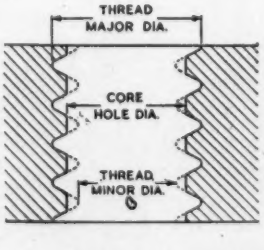
Adequate Depth of Thread in Tapped Holes

THE ways in which threaded holes in components are specified range from the bald instruction "Tap ¼ B.S.F." (which leaves the choice of tapping drill entirely in the hands of the fitter or machine-shop operative) to the very precise instructions often given on aircraft component drawings. These sometimes insist on the use of tapping drills approximating far closer to full theoretical depth of thread than is really necessary. Since tapping is a fairly slow operation, and is much slower still when unnecessarily tight holes are specified, with the added expense of greater risk of tap breakage, the results of an investigation into the relationship between core hole size, tapping torque and thread strength, recently reprinted by the Production Engineering Research Association, should be studied by all those who have to specify threaded holes. The percentage depth of thread produced by the various sizes of tapping drill available are given in the accompanying table for sizes ranging from 2 B.A. to 1 in. B.S.W.

The investigation, which was carried out in order to determine the relationship between core hole size and tapping torque when tapping various materials, and the effect of core hole size and depth, or length of tapped hole on the strength of a threaded assembly, was carried out under carefully controlled conditions using specially designed tapping machines. These incorporated a positive feed to give accurate pitch control. The tap holders used were adapted to provide a rigid drive to the tap, at the same time ensuring that the tap remains concentric with the workpiece during the tapping cycle. Locating fixtures used were designed to accommodate various specimen widths, sufficient clearance in the jaws being allowed to take up any slight eccentricity of the core hole relative to the locating flats of the specimen. A specially designed dynamometer for measuring tapping torque, a recording unit and torsion and tensile test attachments designed for the purpose were used in the investigation. Commercial 18-4-1 high-speed steel taps were used for the tests, manufactured to B.S. 949. The metals on which the tests were carried out were "20" carbon steel En 3b, stainless steel En 56A, cast iron and aluminium alloy DTD 423B.

The conclusions reached included the following:

With a depth of thread of only 60 per cent in a threaded assembly in which 65-70 t.s.i. high tensile steel bolts were used, and where the tapped hole depth is equal to the thread major diameter, the strength of the bolt is less than the strength of the tapped threads. Where the depth of tapped hole is equal to or greater than the thread major diameter, the strength of the threaded assembly is not increased by



Percentage Depth of Thread $= \frac{A}{B} \times 100$

where

A = Thread Major dia. — Core Hole dia.

B = Thread Major dia. — Thread Minor dia.

Definition of percentage depth of thread.

Thread Size	Stock Drills				Percentage Depth of Thread
	in.	mm.	Wire or Letter	Equivalent Dia. in.	
2 B.A.			23*	0.1540	81
		3.95*		0.1555	77
	5/32			0.1562	75
			20*	0.1610	63
		4.10*		0.1614	62
3/16" B.S.F.	5/32			0.1562	78
			22*	0.1570	76
		4.00		0.1575	75
			20*	0.1610	66
		4.10*		0.1614	65
		4.15*		0.1634	60
¼" B.S.F.		5.40*		0.2126	76
			3*	0.2130	75
	9/32			0.2188	63
		5.60*		0.2205	60
			2*	0.2210	59
5/16" B.S.F.	11/64			0.2656	81
			H	0.2660	80
		6.80*		0.2677	77
		7.00		0.2756	63
			J	0.2770	61
⅜" B.S.F.			P	0.3230	81
		8.25		0.3248	78
		8.30*		0.3268	75
	11/64			0.3281	73
		8.50		0.3346	63
½" B.S.F.		11.10*		0.4370	79
	7/32			0.4375	78
		11.40*		0.4488	64
	11/64			0.4531	59
⅝" B.S.F.		14.00		0.5512	81
		14.50		0.5709	59
¾" B.S.F.		17.00		0.6693	76
	11/64			0.6719	73
		17.25		0.6791	66
	11/64			0.6875	59
1" B.S.F.		23.00		0.9055	74
	11/64			0.9062	73
		23.25		0.9154	66
	11/64			0.9219	61
3/16" B.S.W.		3.70*		0.1457	78
			26*	0.1470	76
		3.75		0.1476	75
		3.90*		0.1535	64
			23*	0.1540	63
		3.95*		0.1555	60
	5/32			0.1562	59
¼" B.S.W.		5.10*		0.2008	77
			7*	0.2010	77
	11/64			0.2031	73
		5.30		0.2087	65
			4*	0.2090	64
5/16" B.S.W.		6.50		0.2559	80
			F	0.2570	78
		6.60*		0.2598	74
			H	0.2660	65
		6.80*		0.2677	63
⅜" B.S.W.		7.90*		0.3110	80
	5/16			0.3125	78
		8.00		0.3150	75
			P	0.3230	65
		8.25		0.3248	63
		8.30*		0.3268	60
	11/64			0.3281	59
½" B.S.W.			Z	0.4130	81
		10.60*		0.4173	78
	11/64			0.4219	73
		11.00		0.4331	63
	7/32			0.4375	59
⅝" B.S.W.	17/64			0.5312	81
		13.50		0.5315	80
		14.00		0.5512	63
¾" B.S.W.		16.50		0.6496	78
	11/64			0.6562	73
	11/64			0.6719	61
1" B.S.W.	9/32			0.8750	78
		22.25		0.8760	78
		22.75		0.8957	65
	11/64			0.9062	59

*These drills are not usually available with taper shanks.

providing a depth of thread greater than 60 per cent in aluminium alloy and 75 per cent cast iron.

The following recommendations are given:

1. When specifying tapped threads, B.S.F. threads should be selected in preference to B.S.W.

2. When tapping steels and aluminium alloys, the depth of thread should be 60 per cent. When tapping cast iron, it should be 75 per cent.

3. When tapping steels and aluminium alloys the depth or length of the tapped hole should be equal to the thread major diameter. When tapping aluminium alloy or cast iron, the length or depth of the tapped hole should be one-and-a-half times the thread major diameter.

These recommendations do not necessarily apply to threads for use in assemblies where resistance to fluid pressure is important.

Abstracted from PERA Report, "Tapping", Part 1.

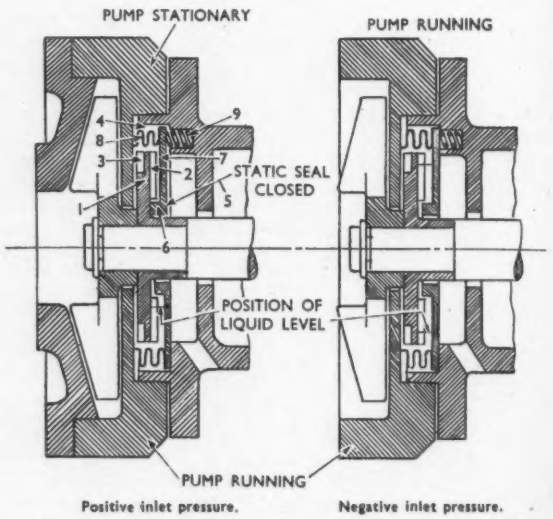
A Novel Hydrodynamic Pump Seal

IN a recent paper delivered to the Institution of Mechanical Engineers by U.M. Barske, Dr. Ing., on "Development of Some Unconventional Centrifugal Pumps", a form of ingenious shaft seal was described which would operate satisfactorily at speeds in excess of 20,000 r.p.m. and at pressures of around 1,500 p.s.i. Mechanical seals employing bellows glands of well-known design had been found unsatisfactory, this being attributed to small swash-plate movements of the rotary sealing face and the fact that the axial spring was not capable of keeping the seal faces in contact at very high speeds.

As the pump itself offered the means of generating pressure without special need for precision work, it appeared logical to apply the same principle to the seal, and use a small open impeller to develop a centrifugal pressure, thus preventing the liquid from escaping through the shaft gap. An example of the type of seal developed is shown in the accompanying sectional drawings.

The seal impeller (1) is a disc provided with straight radial blades on both faces, the outer blades (2) being normally longer than the inner ones (3). It is accommodated in a separate chamber (4), which communicates through a gap near the shaft with the inside of the pump casing. In stationary conditions, this chamber (4) is filled with liquid and sealed by a contact seal (5). The non-rotating seal ring (6) is attached to an axially movable disc (7) which forms the outer wall of the seal chamber (4) and whose periphery is tightly connected to the pump casing by means of a metal bellows (8). External springs (9) ensure a close contact of the mating seal rings.

When the pump is started the centrifugal pressure in the seal chamber, developed by the rotation of the seal impeller,



gradually releases the contact pressure of the seal ring (6) and, above a certain speed, the internal pressure overcomes the spring load and separates the members (1) and (6) of the static seal. This does not happen, however, until a solid liquid ring, which balances the pump inlet pressure, is formed. This is shown on the lower half on the left-hand section. A complete and safe seal is thus provided which need not be manufactured to close tolerances.

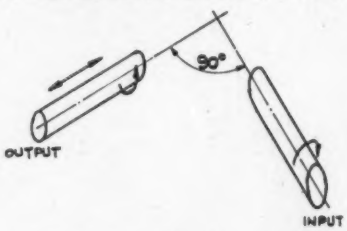
Useful Thermoplastic Cloth Cutter

DURING the past few years thermoplastic filter cloth has become widely used in the processing industries. This is due to its great mechanical strength and superior resistance to corrosive conditions. Cutting the cloths in the plant or pilot laboratory to fit the various sizes and shapes of filters, particularly filter presses, became a problem because of fraying of the cut edges. In general, this has been solved by hot cutting, using a roller knife heated in a gas flame which is then drawn along the cloth, melting it in two, the edges being sealed upon cooling. Filter press cloth holes were similarly cut using a heated arch punch or piece of metal tubing of the correct size. The obvious disadvantages of this method are the rapid cooling of the tools, requiring frequent reheating, and the unavailability of gas in many locations. To overcome these points, successful self-heating cutting tools were devised.

The basic hot cutter was made by simply hammering out the copper point of a heavy-duty electric soldering iron into a blunt knife edge. This electrically-heated cutter is then drawn along the edge of the filter cloth template, melting the cloth and automatically sealing the cut. A plywood backing board is used to protect the work surface.

PROBLEMS IN DESIGN

Here is this month's problem (set by G. T. Dormer):



Devise a mechanism whereby an input shaft, rotating unidirectionally, shall drive an output shaft at half its own speed and at the same time cause it to perform one complete reciprocation for each of its own reciprocations.

Best solutions to "Problems in Design" are published and paid for. Send your solution for this month, with a drawing or diagram (in Indian ink and not more than 12 × 12 in., please !), to The Editor, "Problems in Design No. 6 (April)". Closing date May 10.

TRENDS IN CONVEYOR BELTING MATERIALS

Changing technological needs call for ever-improving service performance. This article discusses the relationship between physical properties and the molecular structure of belting materials, and defines belting requirements in relation to service

by J. A. HARDMAN, M.Sc.*

THE need for driving bands, conveyor bands, gaskets and diaphragms first arose at the end of the eighteenth century. Men turned first to leather and then to textiles as the only flexible materials that they knew. The *Millers' Guide*, published in Philadelphia in 1795, refers to the use of a "broad endless strap of thin pliant leather revolving round two pulleys in a case or trough". The discovery of vulcanisation by Thomas Hancock in England and Charles Goodyear in America opened new possibilities, and in the second half of the nineteenth century the use of rubber-covered canvas belts for conveyors slowly became an accepted practice. Today the annual output of conveyor belting of all kinds in the U.K. alone is probably in excess of 15 million ft.

As the technology of mechanisation develops, increasing demands are made of equipment. In the case of conveyor belts, this means longer hauls between transfer points, with correspondingly higher operating stresses; belts are required to handle increasingly destructive materials in ever-increasing amounts. A wide range of new high polymers has been developed by scientists over the past thirty years, and these are now being rapidly marshalled into service by belting technologists in an effort to cope with the demands for improved performance.

The term "high polymer" is used by chemists to describe a material having large molecules built up from smaller units with some measure of geometric regularity. For our purpose it is convenient to consider them as falling into two categories: namely, those having two-dimensional molecules and those in which the molecules are, or are capable of becoming, three-dimensional.

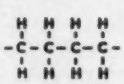
Most high polymers are organic chemicals; by this is meant that their main structure consists of carbon atoms. Two-dimensional high polymer molecules consist of long chains of carbon atoms having various atoms attached to this chain in a repeating pattern of greater or less regularity. The greatest regularity is usually found in naturally-occurring high polymers. Synthetic polymers often leave something to be desired in this respect, and chemists are constantly searching for new techniques to control polymerisation reactions so as to achieve greater uniformity in the molecular configuration of their creations.

The physical properties of the bulk polymers are determined to a large extent by the nature and distribution of the atoms attached to the carbon chain. Other factors are the length of chain and chain length distribution. In two-dimensional polymers the long molecules have no direct linkages between molecules, and are therefore capable of movement relative to each other. They are held together by secondary cohesive forces having their origin in the electronic structure of the individual atoms of which they consist. It is easy to visualise that the magnitude of these intermolecular forces for a given polymer will depend upon the nature and arrangement of these atoms, and that these forces will, among other things, determine such physical properties as hardness, cold flow and resilience.

Again, for this purpose it is useful to subdivide three-dimensional polymers into two groups. In the first group the molecules are built up into a three-dimensional network from small units. These materials are usually hard, rigid materials, of which bakelite resin is a good example. The second group is the one which is of interest in conveyor belt technology, and in this case the molecules are two-dimensional and independent, but capable of being linked together by means of chemical reaction which can be induced to take place by heating or the application of some other form of energy. Natural and synthetic rubbers fall into this category, and the process of cross-linking is known as vulcanisation.

Before this cross-linking reaction is promoted the materials are thermoplastic. As the reaction proceeds they become progressively less thermoplastic, since the molecules can no longer slide past each other under continued, deformative stress. This, of course, is the basis of the processing of rubber. Prior to the cross-linking, the material can be pressed into shape and temporarily adhered to itself. The cross-linking reaction is then promoted by the application of heat, yielding the product with which most people are familiar.

The kind of relationship which exists between molecular structure and the properties of bulk polymers is best illustrated by way of a few examples. It is nowadays common knowledge that the simplest two-dimensional organic molecule is the paraffinic chain



which is the basis of paraffin oil, petroleum jelly, paraffin

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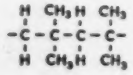
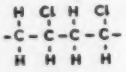
wax and polyethylene. All these materials show similar chemical inertness, and the progressive change from a mobile liquid, on the one hand, to a relatively rigid solid, on the other, is basically attributable to decreasing mobility of the molecules at room temperature with increasing chain length.

Introduction of some irregularity in the chain structure



as in polyisobutylene yields a polymer having greater molecular mobility even with relatively long chains, so that the bulk material, whilst retaining chemical inertness, is somewhat rubbery in appearance and behaviour. However, as the chains are not interlinked, it is highly thermoplastic and even at room temperatures displays considerable cold flow, which is attributable to the reduced effectiveness of the intermolecular forces brought about by the presence of the side groups.

The basic structure of p.v.c. is



in which rather the reverse effect is observed. The presence of the chlorine atom increases the strength of the intermolecular forces, yielding a hard, tough solid which, whilst still exhibiting thermoplasticity, only begins to become rubber-like at temperatures well above 100 deg. C.

In contact with hydrocarbon solvents two-dimensional hydrocarbon polymers generally soften and finally the bulk polymer begins to disintegrate, but a high degree of regularity in the structure of the molecule can slow this process down as in the case of polyethylene. On the other hand, polar solvents such as water, alcohols, acids and alkalis have little effect.

Similarly, polymers such as p.v.c., polyvinyl acetate, etc., are attacked by solvents such as ethyl acetate, and in fact high-boiling-point esters such as di-octyl phthalate are used as plasticisers in making flexible p.v.c. products, on account of their compatibility with this material.

With three-dimensional polymers, whether produced by direct polymerisation or by cross-linking of two-dimensional polymers, the effect of solvents is much the same; but in this case, instead of disintegrating, the polymers merely imbibe the solvent and swell until some equilibrium condition is reached. The greater the compatibility of the solvent with the polymer, the more rapidly is equilibrium reached, and the effect is further accelerated by heat.

The rate and amount of swelling can also be influenced by the number of cross-linkages, a large number of linkages giving greater resistance to swelling. As the amount of cross-linking increases, however, a polymer becomes progressively less flexible; ebonite is a typical example of a highly cross-linked polymer.

The mechanism whereby cross-linking is achieved is usually associated with the presence of unsaturated linkages in the molecular chain of the two-dimensional polymer. When polymers are vulcanised to the flexible stage some of these unsaturated linkages remain unreacted. For the same reason that these unsaturated bonds readily take part in the cross-linking reaction, they also render the main chains more susceptible to oxidative attack. This may take place in two ways, i.e., by rupturing the main chain or by producing further cross-links. The first of these produces degradation and stickiness as the chains become progressively shorter; the second produces hardening and cracking. As in the case of solvent action, the effect is accelerated by high temperatures.

TABLE 1. General characteristics of fibres

Property	Cotton Standard American	Rayon Viscose	Modified Rayon	Nylon	Terylene
Tenacity G/D	Range 2·0–4·9	Range 2·3–4·3	Range 5·0–10·0	Range 4·5–8·0	Range 4·0–7·0
% Elongation at break	Range 3–7	Range 9–20	6	Range 19–30	Range 11–30
S.G.	1·53	1·52	1·50	1·14	1·38
% Moisture absorption at 95% R.H.	24–27	27	20	8	0·5
Effect of heat	Decomposes 150°C.	Decomposes 180–200°C.	Decomposes 150°C.	Melts at 250°C.	Melts at 250°C.
Modulus of elasticity G/D	60	95	95	40	120

TABLE 2. General characteristics of ducks and fabrics based on the principal fibres

Property	Cotton Standard American	Rayon Viscose	Rayon Fortisan	Nylon	Terylene
Effect of ageing	None	Slight	Slight	None	None
Effect of mildew	Attacked Reduced when bleached	Attacked	Attacked	Not attacked	Not attacked
Strength retention after water immersion—%	109	70	80	92	100
Strength loss % on impact*	25	22	36	7	8·5
Tear value (across warp) lb.†	170	200	220	900	900
Effect of oils	Generally none. Some strength reduction can occur in staple fibre-based fabric due to reduction in fibre to fibre cohesion				

* On a 5-ply belt after impact of 130 ft. lb./sq. in.
† On a 5-ply belt, no covers, double tongue method.

TABLE 3. General characteristics of compounded stocks based on natural rubber and some synthetic rubber types

Property	N.R.	GR–S	P.V.C.	Neoprene	Butyl	Nitrile	Hypalon
Coefficient of friction	Good	Good	Poor to Good	Good	Good	Good	
Flame resistance	Very poor	Very poor	Excellent	Good	Very poor	Poor	Good
Anti-static	Good	Good	Fairly good	Good	Good	Good	Good
Age resistance	Good	Good	Excellent	Excellent	Excellent	Excellent	Excellent
Cut and tear resistance	Good	Good	Fair	Good	Good	Good	Fair
Abrasion resistance	Good	Good	Excellent	Good	Good	Good	Good
Temperature sensitivity	Low	Low	Fair	Low	Low	Low	Low
Oil resistance	Poor	Poor	Excellent	Good	Poor	Excellent	Good

These tables are reprinted from *Proceedings of the Institution of the Rubber Industry* Vol. 5, No. 5.

Temperature Resistance

This question of temperature resistance is of prime importance in conveyor belt technology, and it is useful to consider it in relation to natural rubber, which is a typical hydrocarbon polymer having residual unsaturation when vulcanised to the flexible state. In the absence of air, natural rubber begins to decompose at a temperature of about 240 deg. C., which is the temperature at which thermal rupture of the carbon-carbon bonds of the main chain begins. In the presence of air, breakdown begins at much lower temperatures, and does in fact proceed slowly at room temperature. This is not thermal breakdown, but the result of oxidative attack. It is accelerated by stress, sunlight and ozone. Fortunately, there are fairly effective remedies which the rubber technologist can enlist to his aid.

The first of these is the use of small additions of anti-

oxidants which divert the attack by oxygen into a harmless side reaction. This type of protection can only be fully effective when the vulcanising reaction is properly balanced.

A second method of dealing with oxidative attack is to modify the molecular structure in such a way as to make the residual unsaturated bonds less susceptible to attack. The introduction of atoms of chlorine at regular intervals produces such an effect, and at the same time resistance to swelling in hydrocarbon solvents is increased. Neoprene is the well-known and well-tried example of such a polymer with built-in age resistance. For the same reason, such polymers are less readily cross-linked, and therefore show somewhat less resilience and greater hysteresis when flexed.

Thus it will be seen that the upper limit of thermal stability for the main chain of hydrocarbon polymers is about 240 deg. C. In practice, the more common two-dimensional saturated polymers become fluid long before this temperature is reached, and at the same time some decomposition may be initiated by the splitting off of side groups. With such materials, of which p.v.c. is an example, the upper limit of temperature at which they may be used effectively is obviously set by thermoplasticity considerations.

With the cross-linked polymers thermoplasticity is of less importance in determining the upper practical temperature limit than are molecular structure and the amount of residual unsaturation which between them determine the rate at which oxidative breakdown can take place. Proper choice of polymer and vulcanising system can slow down this process, but it must be remembered that, being a chemical reaction, the rate at which it takes place will approximately double for every 10 deg. rise in temperature, so that the fact must be faced that polymers capable of being cross-linked by any process which is practical on a large scale still fall far short of achieving the ultimate of thermal stability.

Silicone rubbers come nearest to this, being suitable for intermittent temperatures in excess of 200 deg. C., but it is well known that these still leave much to be desired in physical properties and are extremely difficult to vulcanise on a large scale.

A further consequence of the presence of unsaturated linkages in the polymer chain is of prime importance to the technology of polymers used in products which are subject to severe wear and tear in service. When fine particle powders such as carbon black are uniformly dispersed in such polymers, strong associative links appear to be formed between the unsaturated polymer bonds and the highly active carbon particle surfaces. This is termed reinforcement and results in greatly increased tear and abrasion resistance. With saturated polymers such as p.v.c. the effect of the addition of such materials is one of dilution, with a corresponding loss in strength.

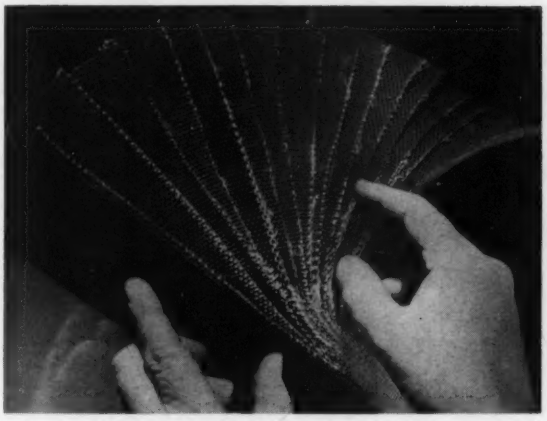
It will readily be realised that the above represents a greatly simplified picture of the highly complex relationship between the structure and properties of certain types of polymer. Nevertheless, it provides a useful backcloth when considering the technical advantages which might be gained in employing such polymers in the manufacture of conveyor belting.

Natural Rubber

Natural rubber is still the most versatile of these polymers. It can be modified within a wide range of hardness and flexibility, and when properly reinforced it is one of the toughest of flexible polymers, being only exceeded in this respect by some of the polyurethane rubbers which are now making their appearance, but which are extremely expensive and very difficult to process.

For reasons explained above, natural rubber is not well suited for handling oily materials such as castings, although a quite reasonable resistance to swelling by oil can be achieved by high carbon black reinforcement. It is subject to ageing, particularly if exposed to sunlight in a strained condition, but proper choice of additives helps greatly to minimise these effects. About 80 deg. C. is considered to be the maximum practical temperature for natural rubber, although much hotter materials can be handled on belts of special construction incorporating a protective surface.

Inspecting and trimming a large Terylene-natural rubber belt for export.



B.T.R. fourteen-ply rubber/Terylene belting for Russia. Maximum working tension of this belting is 59 tons.

The resilience of properly compounded and vulcanised natural rubber adds much to the resilience of the belt structure as a whole, giving high-impact resistance and contributing greatly to resistance to permanent elongation. Despite the introduction of many new polymers, natural rubber is still the best all-round material for surface belting, but its ready combustibility makes it unsuitable for underground work. Butyl rubber is somewhat similar to natural rubber, being more heat and age resistant but less resilient.

As may be expected, the substitution of neoprene for natural rubber confers greater oil, heat and age resistance, but usually at the sacrifice of some toughness when compared with the highest grades of natural rubber. Neoprene also shows a fair degree of fire resistance.

Acrylic nitrile-based rubbers are more oil resistant still. Such polymers are the basis of machinery oil seals and show remarkable resistance to attack by hot oil. Age and heat resistance are better than those of natural rubber, but inferior to those of neoprene. This oil resistance creates its own problems in the manufacturing process, since

difficulty is often experienced in bonding the components of a belt together before vulcanisation.

Since the Cresswell Colliery disaster a great deal of attention has been focused upon fire-resisting p.v.c. belting. The use of plasticised p.v.c. in conveyor belting represents an entirely different case from any considered so far, since p.v.c. is a fully-saturated two-dimensional polymer which does not form any intermolecular cross-links. Unplasticised p.v.c. is hard and rigid at room temperature, having a tensile strength of about 6,000 p.s.i. As used in conveyor belting, it is blended with one or more plasticisers, which, on account of their compatibility with p.v.c., act as internal lubricants, so that the plasticised polymer is flexible and rubber-like at room temperature. It is essential that the dispersion of plasticiser be on a molecular basis, since failure to achieve this means that small aggregates of p.v.c. are dispersed in a mixture of plasticiser and p.v.c. In this state the material is stiffer than it should be, tensile strength and tear resistance are poor, and premature cracking often occurs. This fault was not uncommon in the early days of p.v.c. conveyor belting.

P.V.C. conveyor belting shows a fair degree of thermoplasticity, but by proper selection of plasticisers quite good low-temperature flexibility can be obtained.

Whilst there is no doubt that plasticised p.v.c. has gone far towards meeting the demand for a fireproof conveyor belt materials, it still falls short of what might be termed the ideal belting polymer. Work is being undertaken in research laboratories and universities which aims at producing polymers which combine the best features of the thermoplastics with those of the rubbers. These newer materials are referred to as graft polymers and block polymers, and it may well be that out of this work will emerge the ideal material for belting, combining in good measure such properties as toughness, abrasion resistance, resilience, oil and acid resistance, age resistance, flexibility and non-inflammability.

Man-made Fibres

No discussion of the use of new polymers in conveyor belting would be complete without some mention of man-made fibres. Space does not permit of anything but brief reference to this aspect of conveyor belt manufacture, which is a subject in itself.

Three types of fibre have found application so far, but it seems quite likely that all will have their place for some time to come. The three types are rayon, nylon and Terylene. All are stronger than cotton. Rayon is highly susceptible to strength loss when wet, although this is much less pronounced in some of the newer high-strength rayons. Nylon and Terylene are practically immune to the effects of moisture and mildew, and the high strength of all these materials permits greater operating tensions or a reduced number of plies.

At the present time cotton and rayon have a considerable price advantage over nylon and Terylene, but in considering this the price of a belt should be related to its working life. For example, a 30 in. × 5-ply Terylene-natural rubber belt handling an average of 180 tons per hour of wet limestone is recorded as having outlasted three cotton belts, thereby yielding a saving of £500 in two and a half years.

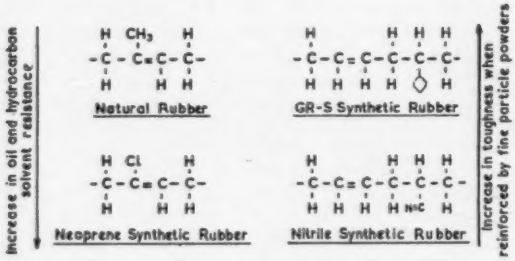
Claimed as the world's longest single flight of conveyor belting, this Goodrich rubber belting delivers 1,000 tons of crushed limestone an hour. The belt is so long it makes only ten round trips in an 8-hr. day even though it moves constantly at 500 ft./min.

Until quite recently, the largest belt that had been made from all Terylene was 36 in. × 4-ply × 282 ft., for handling boiler ash at I.C.I. Witton, but a very large export order has now been successfully completed, for some six miles of all-Terylene belting, some of which was 78 in. wide × 14-ply.

It is clear from this that Terylene has emerged from the field-trial stage so far as conveyor belting is concerned. Even so, there is still some way to go in learning to control this fibre under different conditions of temperature and stress. The high-modulus, low-stretch characteristics of fabrics made from this material demand great uniformity in control if the full benefit of uniform stressing is to be achieved, and for this purpose it is essential that processing equipment of adequate strength be available.

In relation to its bulk, nylon is the strongest of all the man-made fibres, and its good abrasion resistance, flex life and resistance to mildew make it admirable for use in belting. Its chief application to date has been as a weft yarn in combination with various other fibres. It seems likely, however, that as experience is gained in controlling the stretch of this fibre during processing it will find increasing application in conveyor belts on account of its remarkable resilience.

Externally, conveyor belts may appear little different today from what they were over fifty years ago, but in terms of performance there is no doubt that great advances have been made. The newer materials described above offer scope for further advances still. Undoubtedly, there will be some difficult cost problems to overcome, but steady application to these on the part of raw material suppliers and belting manufacturers will eventually ensure real and lasting benefits to users.


Increase in oil and hydrocarbon solvent resistance
Natural Rubber
GR-S Synthetic Rubber
Neoprene Synthetic Rubber
Nitrile Synthetic Rubber
Increase in toughness when reinforced by fine particle powders

Structure of the basic units of some well-tried rubbers.

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OVERSEAS NEWSLETTER

A monthly digest of reports from our foreign correspondents of other countries' current achievements in research and development work

Automatic Painting

The painting of tubular radiators for power transformers has always presented a difficult problem, for the close spacing of the tubes renders it extremely difficult to apply even coats with brush or spray gun. Dip painting is the ideal method, but size and weight make it impracticable to dip complete radiators, so the logical procedure is to treat each individual unit before assembly.

The welding shop of a large Belgian manufacturer of electrical equipment (Atelier de Constructions Electrique de Charleroi) has recently put into operation an automatic painting installation. After completion of testing under pressure and sand blasting the surfaces, the radiators are protected with glycerophthalic resin-base paint by immersion in three consecutive baths. Application of each one of the three coats calls for the four following operations: dipping, draining, oven drying and cooling. These operations are performed consecutively by an automatic control system whose cycle of 7 min. may be adjusted by a time switch.

The draining operation, which involves an absorbent roller to remove the last drops immediately before the radiator passes for drying, is carried out in infra-red ovens which move on rails. As soon as the chain carrying the radiator unit has moved to the next position, the oven automatically advances to surround the radiators. The number of infra-red units is adjusted to suit the size of radiators the temperature being controlled by means of thermocouples. The heating time is controlled by a time switch, which also controls the withdrawal of the ovens and the movement of the chain as soon as the ovens arrive in the withdrawal position.

The radiators are cooled at the next position by fans which reduce the temperature to a value suitable for the application of the next coat or for storage while awaiting the assembly of the complete units. When the store is full, an interlock (which is controlled by a microswitch operating a relay sensitive to the passage of the radiators into store) stops the movement of the chain when the last carriage to enter the store holds the microswitch permanently closed.

Potting with Alumina Powder

A new approach in the protection of electronic components is claimed to have been made by Bell Telephone Laboratories, using alumina powder (aluminum oxide) to insulate or pot transformers and other electrical components in hermetically-sealed cans.

In many applications, electronic and electrical components need protection from extreme environments, and a common practice is to seal these components hermetically inside a metal can. However, when enclosed in this way, the internal temperature may be increased to a point where the life of the device is seriously reduced. In conventional practice, therefore, a heat-transfer material is placed in the can to dissipate the heat from the device to the atmosphere, in order to reduce the overall temperature rise.

Popular conventional potting compounds include mineral-filled asphalts such as sand asphalt. This has good heat-transfer properties, but it melts at the relatively low temperature of 135-150 deg. C. When it melts, it expands, threatening the hermetic seal and often damaging the component.

Alumina powder has the advantage of a melting point of over 1,500 deg. C. (well above the operating temperatures of any electrical apparatus); it does not expand or contract to any noticeable extent under wide fluctuations of temperature; and it does not need to be cured or vulcanised for use. Thus, little or no strains are imposed on the component as would be the case when using conventional materials.

Another advantage over asphalts, epoxy resins and other similar potting compounds is that alumina powder maintains its dry granular form in use; the component may therefore be inspected or repaired by merely breaking the seal on the can and pouring out the powder.

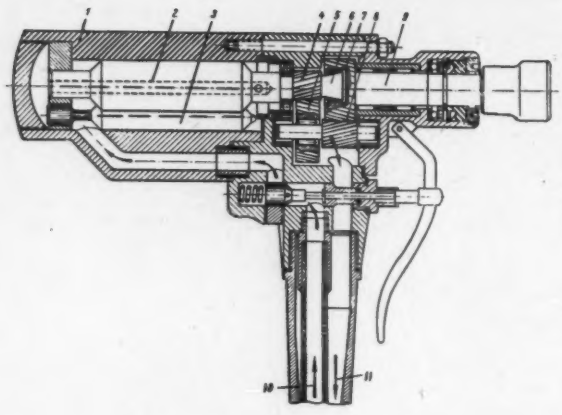
Since alumina is stable to high temperatures, it can be used as a single potting compound to cover a range of temperatures, and, being completely inert, there is no fire risk either during potting operations or in use.

By using the alumina in the form of spherical granules the abrasive characteristics of more irregular shapes are eliminated. The test programme on alumina potting compounds was performed on typical medium-size electronic power transformers which were impregnated with a polymerising varnish before potting and encasing.

Electroplating Tantalum

Coating tantalum with a surface film of another metal could offer some technical advantages, but the process offers serious difficulties, although tantalum is a hydrogen acceptor and is thus easily oxidisable anodically. In investi-

Bell Telephone have developed the use of alumina oxide powder for potting electrical components. Certain advantages are claimed over conventional asphalt or plastics materials.



Russian two-speed hydraulic nut driver. 1. Body. 2. Driving screw. 3. Idling screws. 4. First reducing gear pinion. 5. Second pinion. 6. Cone of limiting torque clutch. 7. Fourth pinion. 8. Third pinion. 9. Spindle. 10. Oil supply. 11. Oil return.

gating electroplating tantalum metal at the Laboratory for Applied Physical Chemistry in Helsinki, the following details were considered:

1. Deposition of a metal with a similar lattice structure or lattice spacings to tantalum or of a metal which alloys with tantalum.
2. Prevention of hydrogen electrolysis with electrodeposition at the surface.
3. Avoidance of the formation of tantalum oxide.

It was found that cleaning the surface of tantalum metal electrolytically in the usual type of baths was not possible. Degreasing as a cathode or anode immediately produces hydrogen embrittlement or the formation of tantalum oxide. It was found that the best procedure was careful treatment with a fine file, followed by a dip treatment in a 50-60 per cent hydrofluoric acid bath for about 30 sec., with a subsequent anodic electrolytic treatment for about 3 sec. at 18·7 amp./sq. ft. current density, in the same bath. After this treatment, the tantalum metal should be placed in the electroplating bath within 10 sec.

The results of the electroplating treatment on the tantalum metal were studied with electrical resistance measurements and microscopic examination. The electroplated coatings on the tantalum metal were heated up to about 400 deg. C. in order to test the adhesion, a bad coating of metal showing a high electrical resistance at the boundary between the metal and tantalum.

With nickel plating, it was found that satisfactory results were obtained in about 80 per cent of the experiments. Research on the silver-plating of tantalum is proceeding.

Two-speed Hydraulic Spanner

A hydraulically-driven nut driver, with either a mechanical or hydraulic reducing gear, and giving two speeds, has been developed by the U.S.S.R. Hydraulic Laboratory of the Research Institute for Agricultural Machinery.

The variant with the mechanical reducing gear has a torque-limiting cone friction clutch which directly connects the screw of the hydraulic motor with the spanner spindle, and a freewheel clutch between the second and third pinions of the reducing gear.

Until the torque on the spindle exceeds the torque limit of a given coupling, the driving screw and the spindle rotate at maximum speed, depending on the supply from the pump. As the torque on the spindle increases, the torque limiting clutch begins to slip. The third pinion then rotates more slowly than the second, which causes the freewheel clutch to engage and the required torque to be transmitted through the reducing gear. Thus, as the nut is tightened, a smooth transition takes place from a high to a low speed, together with an increase in the torque.

In the variant of the two-speed spanner with the hydraulic reducing gear instead of the four pinions, a vane in the same casing is connected to the spindle through the freewheel clutch. The spindle forms a continuation of the driving shaft and runs at high speed when rotating freely; the tightening vane remains stationary. As the nut tightens and the spindle decelerates, the oil pressure rises abruptly and the piston valve is moved to a position where communication is established between the pressure cavity and the cavity of the tightening vane. The maximum pressure developed by the pump acts on the large surface of the vane and sets up the required tightening torque which is transmitted to the spindle through the freewheel clutch. The spindle speed is thereby reduced by a factor corresponding to the load area of the vane which exceeds the corresponding area of the motor screw. It is thus a case of hydraulic reduction.

As the operation is completed and pressure is cut off, a spring returns the piston valve to its original position, which, in turn, causes the tightening vane to revert to its initial position.

Dynamo Regulators

The two main present-day regulating systems for the automobile dynamo are the regulator with drooping characteristic curve, also referred to as resilient regulator, and the regulator with current-voltage control-system. The regulator with current-voltage regulation provides for a better utilisation of the possible capacity of the dynamo up to peak load and gives perfect overload protection to the machine through rapid regulation of the voltage in a downward direction when the peak load has been exceeded. Such advantages are well known to be obtainable by an additional regulator unit, the so-called current regulator. A third type of regulator recently introduced in Germany by the Robert Bosch Co. has a characteristic curve similar to that of the current-voltage regulator without requiring a separate current regulator element.

The Variode, as it is called, is a constructional semiconductor element with a so-called p-n transition and a voltage-dependent resistor.

A feature of the Variode is its characteristic of allowing only a very weak current to pass through when applying a low voltage in the flow direction; it is only from a certain voltage upwards that the current rises very considerably, corresponding to the characteristic curve. It is this feature which is utilised for obtaining an approximate current-voltage control-system.

With low dynamo load, i.e., low current, the voltage drop is still insignificant and the Variode consequently permits only a very weak current to pass through (slightly drooping section of the characteristic curve). From a certain voltage drop, corresponding to a definite dynamo load, the current in the control winding rises very considerably in conformity with the characteristic curve of the variode. The resistance in the main current conductor is then so rated that the variode opens at the admissible maximum current. The magnetic force thereby generated (number of ampere turns) in the control winding brings about a rapid decrease in the dynamo voltage, thereby protecting the dynamo against overload in a manner similar to that brought about by the current-voltage regulator.

A feature of the Variode is its temperature dependence, which takes effect only within the limits of the characteristic curve. If the temperature of dynamo and regulator and cut-out rises, the current is limited to the permissible value; this feature makes better utilisation of the dynamo, especially in city traffic, thereby also improving the battery charge in cold weather and short trips at low speed.

NEW IDEAS IN DESIGN

Outstanding products in current manufacture

A Universal Tool Milling Machine of Wide Utility

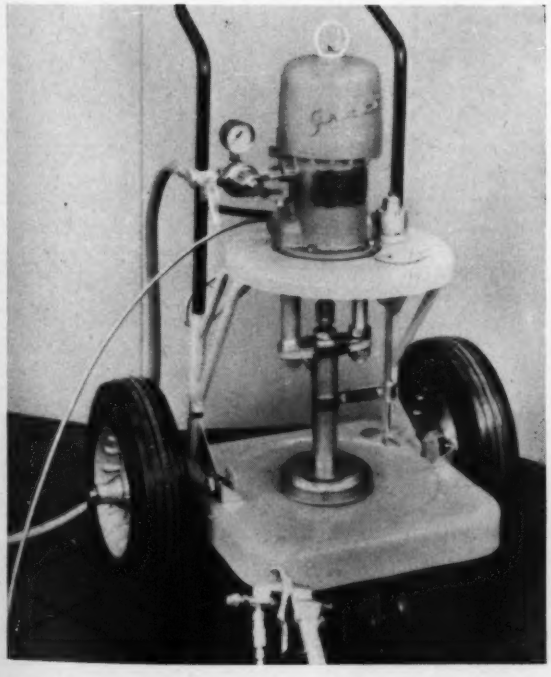
THE Maho MH800 universal tool milling and die-sinking machine, made by Mayr, Hörmann & Co. (and available in this country from Monks & Crane Ltd.) is one of a range of such machines which, by close attention to detail design and the range of accessories available, are suitable not only for the production of jigs, fixtures, cutters, etc., but can also be used for jig-boring.

The horizontal and vertical table feed is power-operated in both directions and is equipped with a gearbox producing 18 rates of feed, and also a provision for rapid traverse in all directions, thus greatly improving operational efficiency. A notable feature is that all operating levers, handwheels and push buttons are conveniently arranged on one side of the machine, with simple directional controls for the feed movements. Scales fitted with verniers facilitate the length of travel of headstock and table. These movements can also be limited by means of adjustable stops, with automatic disengagement if power feed is used. Provision is also made for the use of dials and slip gauges when these are required. The graduated dials on the handwheels are of large diameter and are easily read, and have fitted verniers.

The electrical equipment comprises one motor each for the spindle, feed gearbox and coolant pump, as well as all necessary switchgear. Starting and stopping of motors is effected through relays arranged in a switchgear cabinet at the rear of the machine.

A larger version of the machine, the Model MH1000, can also be fitted with an automatic copying attachment and optical co-ordinate setting devices.

New Airless Paint Spraying System



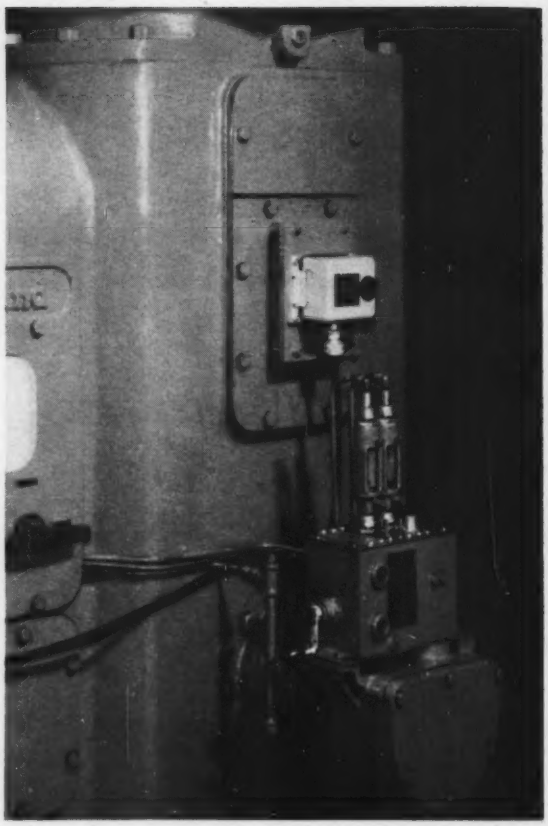
THE truck-mounted Hydra-Spray, now available in this country from A. Bullows & Sons Ltd., does not use compressed air to atomise the paint, and one of the principal advantages claimed is that virtually all over-spray is thereby eliminated, approximately three gallons of paint out of every ten gallons used being saved.

The Hydra-Spray employs a reciprocating double-acting air motor, coupled by a connecting rod to a reciprocating double-acting pump which multiplies the fluid pressure to twenty times the air pressure admitted to the air motor. An incoming air line pressure of 80 p.s.i. enables the pump to develop 1,600 p.s.i. fluid pressure. The high hydrostatic pressure produced, which can range from 1,000-3,000 p.s.i., is confined to the pump and to the 20-ft. length of stainless-steel braid-reinforced p.t.f.e. tube to the spray gun. This hose is said to have a bursting pressure of 10,000 p.s.i. The spray gun is fitted with a tungsten carbide nozzle to resist the erosion of abrasive paint when under high pressure. At no time is there any pressure in the paint container, which has been removed in the photograph to show the pump and paint agitator.

The unit shown in the photograph is the 226-062 truck-mounted unit which is supplied with a ten U.S. gallon pail and 15 ft. of ½ in. i.d. air supply hose and 20 ft. of ¼ in. i.d. braided p.t.f.e. high-pressure hose and Hydra-Spray gun.

The maximum permissible length of fluid hose to each gun is 80 ft., and it is claimed that two guns can be used simultaneously with unimpaired performance.

Vibration-sensitive Device to Prevent Mechanical Malfunction



WHEN the vibration level of the Vibraswitch Model 66 malfunction detector exceeds normal by a pre-selected amount, an internal switch closes, actuating either an audible warning system or a shut-down circuit, before costly damage occurs. It has been designed for maintenance-free service in permanent installations where water-tight enclosures are required, and is claimed to be suitable for the detection of failing bearings, broken blades and similar malfunctions which cause increased imbalance or high-frequency vibration. (It is made by Robertshaw-Fulton Controls Co.)

In some instances, when a malfunction occurs, the vibration is a low-amplitude high-frequency "noise" and is clearly audible for several seconds prior to complete failure. An example is the vibration produced by a failing bearing. The latter is of extremely small amplitude and would not be measurable with a displacement vibrometer. The sensitivity of the Vibraswitch is claimed to increase with frequency, making it equally suitable for sensing either increases in amplitude at the operating speed, or high-frequency chatter, noise or shock associated with many types of malfunction.

Each curve in Fig. 1 represents the summation of a fundamental wave form characteristic of normal vibration superimposed by a typical high-frequency, low-amplitude vibration. In terms of velocity and acceleration, the change is pronounced, but the relative increase in displacement is negligible. The ability of the Vibraswitch to detect bearing failure is said to have been thoroughly proven through time-tested industrial use.

The device, a sectional diagram of which is shown in Fig. 2, employs a magnetic circuit opposed by inertial and adjustable spring forces in the actuating mechanism. The armature is constrained to only one type of movement by a frictionless flexure pivot composed of two overlapping blocks and a leaf spring loaded in one direction to hold the blocks together. The armature rocks on the pivot, being forced in one direction by the adjusting spring and the other direction by the magnet. When the entire assembly is subjected to vibration perpendicular to the base, the peak acceleration times, the effective mass of the armature produces an inertial force aided by the spring, tending to pull the armature away from the stop pin and open the air gap. When the peak acceleration exceeds a pre-selected level, the armature leaves the stop pin, increasing the gap with the armature continuing to move up until it strikes the latch magnet, actuating the switch during the upward travel. The Vibraswitch may be reset by depressing the reset button or applying power to the electrical reset coil. The effect of temperature in the mechanism is negligible, as the elastic modulus of the adjusting spring and the magnetic flux through the air gap both decrease slightly with increasing temperature.

The sensitive axis of the unit is perpendicular to the mounting base. For machines with vertical or horizontal shafts it is mounted in an upright position on a near-vertical surface and is sensitive to the horizontal component of vibration. On machines with a low vibration level it may be mounted on a bearing pedestal or equidistant between

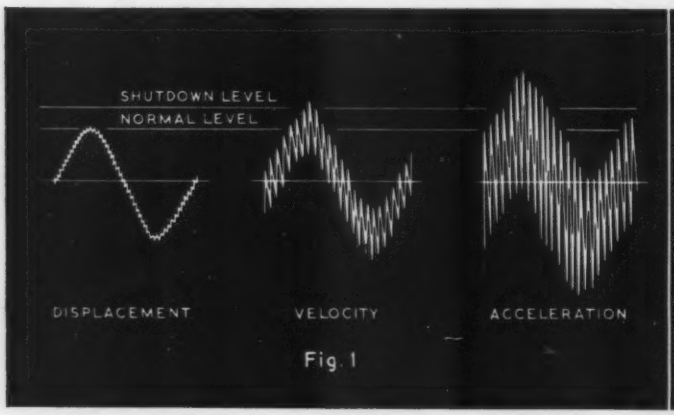


Fig. 1

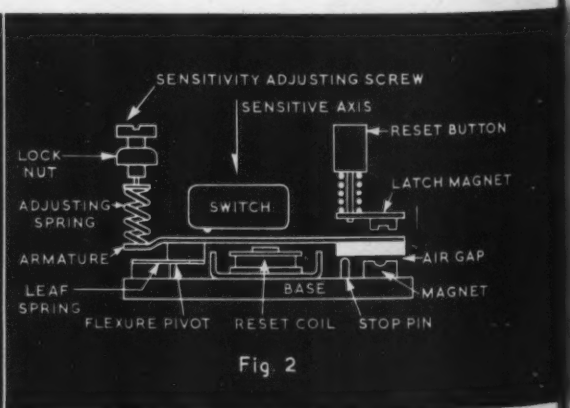
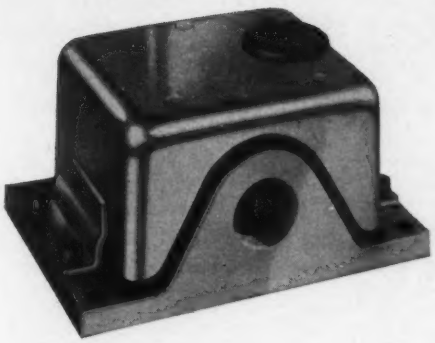


Fig. 2

bearings near the centre of the machine. Exact location, however, is said to be not critical, as the setting procedure automatically accounts for the normal or existing vibration that is encountered.

The Vibraswitch, which measures 5¼ × 3¾ × 2¾ in., weighs 2·5 lb. It is claimed to be sensitive to 0-4·5 g., adjustable 1 g. per turn of the adjusting screw. The accuracy claimed is ±5 per cent of full range from 0-300 c/s or 18,000 r.p.m. The coil power required is 10 watts, intermittent duty. Standard nominal voltages are 6, 12, 24, 48 and 115 d.c.



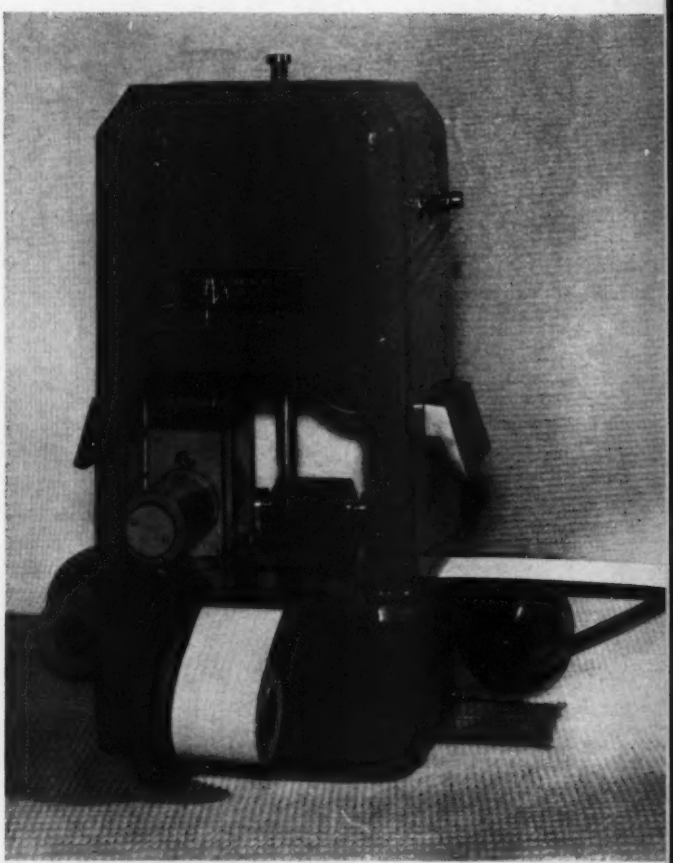
A Pitch and Roll Indicator for Assessing Vehicle Ride

FOR the accurate assessment of the quality of ride provided by a motor vehicle, the Toledo Woodhead-Plint pitch and roll indicator, a product of Woodhead Springs Ltd., would appear to provide the solution in a compact form without the need for an elaborate experimental set-up using several accelerometers at various positions in the vehicle. The instrument measures only 14½ × 14½ × 16½ in., weighs 30 lb. and operates on a dry accumulator.

Vehicle motions can be divided into six categories: accelerations in the vertical, fore-and-aft and transverse directions and angular movements about a vertical axis (yaw), a transverse axis (pitch) and a longitudinal axis (roll). The manufacturers, having decided that pitch and roll sufficiently defined the motion of the vehicle, developed an instrument that would compare its angular position at any instant with a line, the direction of which remained fixed in space in relation to the vehicle. In the pitch and roll indicator this datum line is provided by a freely-suspended gyroscope, positioned with its axis approximately perpendicular to the surface on which the vehicle is travelling. The gyroscope carries a pointer which moves across a recording surface. The body of the instrument rests on the floor or some solid supporting structure attached to the body of the vehicle under test, and so takes part in the angular movements of the vehicle. By means of a recording device, which is the subject of a patent application, simultaneous records are produced of movements in pitch and roll. The recording method is entirely frictionless, thus avoiding any disturbance of the gyroscope, and the curves of angular movement are available for inspection within 6 sec. of being taken.

A strongly made cast aluminium housing carries a gyroscope, which is driven at about 5,000 r.p.m., in ball-bearing gimbals. The complete assembly is accurately balanced so that it shall not be affected by acceleration in any direction. A pointer attached to the gyroscope housing moves in close proximity to an insulated recording table attached to the body of the instrument. Between the pointer and the recording table two strips of spark-sensitive graph paper are traversed, one below the other, in directions at right angles, by means of rubber feed rollers. The feed rollers are driven at a surface speed of 20 mm./sec. by a governed motor. Sparks, generated by a small ignition coil at a frequency of 30 per sec., traverse the gap between the pointer and the recording table and in so doing produce records, in the form of dotted lines, on the sensitive paper strips.

The instrument is so positioned in the vehicle that one paper strip moves parallel to the axis and so produces records of roll, while the other strip moves transversely and produces records of pitch. After recording, each strip emerges from a slot in the side of the instrument and is automatically reeled on to a drum. Detachable inspection tables allow the records to be examined as they emerge.



The instrument is loaded with 100-ft. rolls of paper, each roll lasting for 25 min. of recording time.

By placing the two graphs, the one showing pitch angle, and the other roll angle, side by side, the combined altitude of the vehicle in both pitch and roll may be read off. Since both records are made simultaneously by a single pointer, an angular movement in pitch results in a distortion of the time scale in roll, and vice versa. Under extreme conditions this can lead to a looping back of the record, but there is no distortion of the angular movements recorded, only of the time base. Should it be essential for any reason to eliminate this distortion, this can be achieved by replotting the records on a true time base, bearing in mind that the recording pointer passes 30 sparks per second. The pitch and roll indicator is claimed to be equally suitable for rail vehicles.

New Books

Engineering Manufacturing Methods. *By Gilbert S. Schaller. Second edition. (McGraw Hill, 74s.)*

ALTHOUGH the success of any engineering design project is ultimately dependent on techniques of manufacture, these are too often considered after the design has been frozen. This book fills an oft-neglected gap between the designer and the production man, and many of the chapters may be regarded as primarily for the design engineer. It clearly indicates fundamentals (and in many chapters the details) of modern processes, their limitations and adaptability. Various chapters deal with ferrous metals, non-ferrous metals and plastics, and powder metals and cermets. The information is practical and indicates the spheres in which the materials should be considered. Others deal with foundry techniques, and here the latest developments in casting processes are discussed. Those sections on hot and cold shaping and heat treatment clearly indicate the possibilities and the effect of deformation and heat-treating cycles.

In the succeeding chapters dealing with all types of machining, grinding and finishing, the most interesting aspect is that of numerical control for machine tools, and the knowledge here could well benefit the designer. In the study of welding and brazing techniques, the design approach is suggested in order to take advantage of each process.

Uranium and Thorium. *By L. Grainger. (Newnes, 25s.)*

This book presents a comprehensive picture of the technology of uranium and thorium. It commences with the basic ore material, showing where the richest ore deposits exist, and illustrates each step through the chemical and physical processes to their final uses in the atomic energy industry.

It has been written in such a manner as to assist scientists and engineers associated with industrial organisations, and who are concerned with the application of fissile materials, but it will also be of very great interest to the layman who wishes to learn something of the materials used in this industry.

The two materials are dealt with concurrently throughout the stages of transforming mineral to metal, their chemical and physical properties, and uses as nuclear fuels with future possible uses of these materials. There is also included a most informative chapter on health hazards, though it is not the intention of the book to deal at length with their safeguards. F.S.

Source Book of the New Plastics. *By H. Simonds. Vol. 1. (Chapman & Hall, 80s.)*

This unusual book combines the functions of an encyclopædia and a survey of the new plastics. It is concerned mainly with primary materials such as the polymers, and although it refers only to the products and future developments of U.S. companies, it nevertheless deals in sufficient detail with chemistry, properties and applications to be related to the various plastics produced in the U.K.

The various types of plastics are described, together with improvements in established materials. The main content of the book details at some length each product of some 150 different plastics-producing companies. Other chapters deal with various aspects of government-sponsored research, which make interesting reading, a brief patent survey and an appendix.

Performance of Lubricating Oils. *By H. H. Zuidema. (Chapman & Hall, 56s.)*

This second edition by the American Chemical Society is a more up-to-date version on this important subject and, for those who are interested in lubrication problems or are concerned with the development, manufacture and use of lubricating oils, this is a most useful book. It covers the processes of lubrication, the rheology, oxidation, bearing corrosion, sludge and lacquer deposition, emulsification and foaming, and manufacturing methods.

The new subjects covered in this edition include multi-grade oils, fretting wear and paper chromatography. The book incorporates many papers published since the first edition and selected references have been added to the bibliography in each chapter. The general information and many of the tables have been increased as new publications have become available, and the book now includes the conversion of various viscosity units.

Although many references are made to American papers and publications which may prove difficult to obtain if further information on the subject of manufacturing methods is required, the book contains a first-class subject index and is well illustrated with many graphs and tables. F.S.

Filler Metals for Joining. *By Orville T. Barnett. (Chapman & Hall, 56s.)*

Parallel with the advancement in the technology of welding, brazing and soldering has been the development of special filler materials to satisfy metallurgical and operating requirements. As the choice of these materials no longer rests with the operator, but with the designer, this book is of importance, since it gives information on all recognised fillers beyond what is normally published as manufacturer's literature.

Although primarily concerned with U.S. filler products, the book provides valuable general information, the first five chapters being directed to different types of electrodes, the welding equipment to use, operating characteristics, costs and applications. Iron powder electrodes are included, together with various ferrous alloys, cast iron, copper, nickel and aluminium electrodes and welding rods. The necessity of surfacing is discussed, together with various aspects of brazing and soldering.

LETTER TO THE EDITOR

Putting a Pint in a Quart Pot?

Sir,

May I make a point about a solution to "Problems in Design" in your February issue? The idea of using hydraulics is sound, but the connection of the pipes to the cylinders in Fig. 12 would give trouble, by reason of the difference in volume between the head of the cylinder and the piston-rod end of the cylinder, the difference, of course, being the volume of the piston rod.

Let us consider two identical cylinders connected as in Fig. 12, the dimensions of which give the following results. Starting with the piston rod extended on the crank cylinder, a movement of 1 in. down gives an output at the head of the cylinder of 20 cu. in. However, the piston-rod side has only taken in 10 cu. in., the difference being the volume of the piston rod. Now if the oil from the piston head of the cylinder is piped to the piston-rod side of the second cylinder, as in Fig. 12, it would produce a movement of 2 in. in that cylinder, and an output of 40 cu. in. from the head. This 40 cu. in. has to go into a space of 10 cu. in. in the first cylinder.

If, however, the connections are reversed, and the cylinder heads piped to one another, and likewise the rod ends of the cylinders, the scheme would work very well.

J. A. Fox

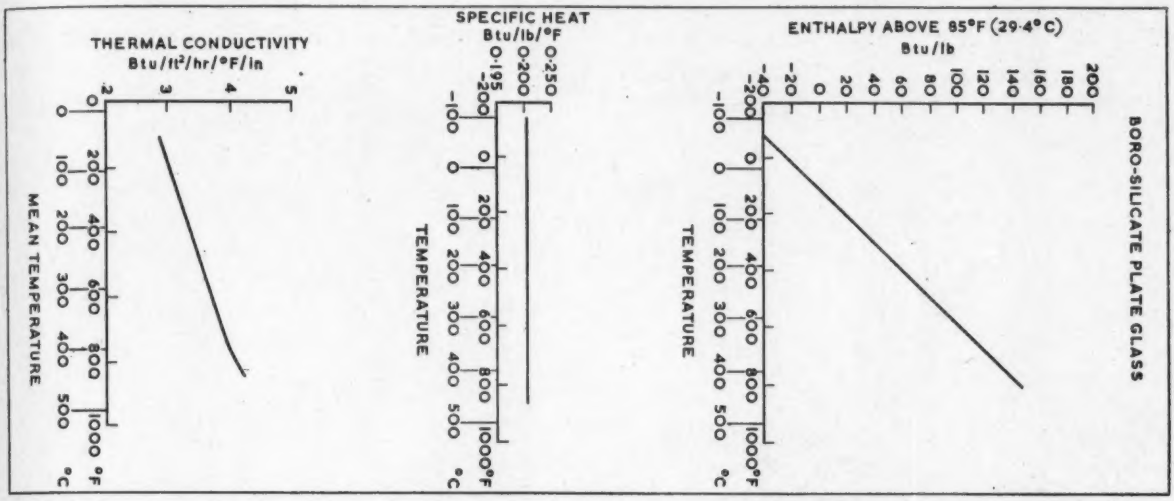
5 Thirlmere Drive,
West Ardsley,
Nr. Wakefield, Yorks.

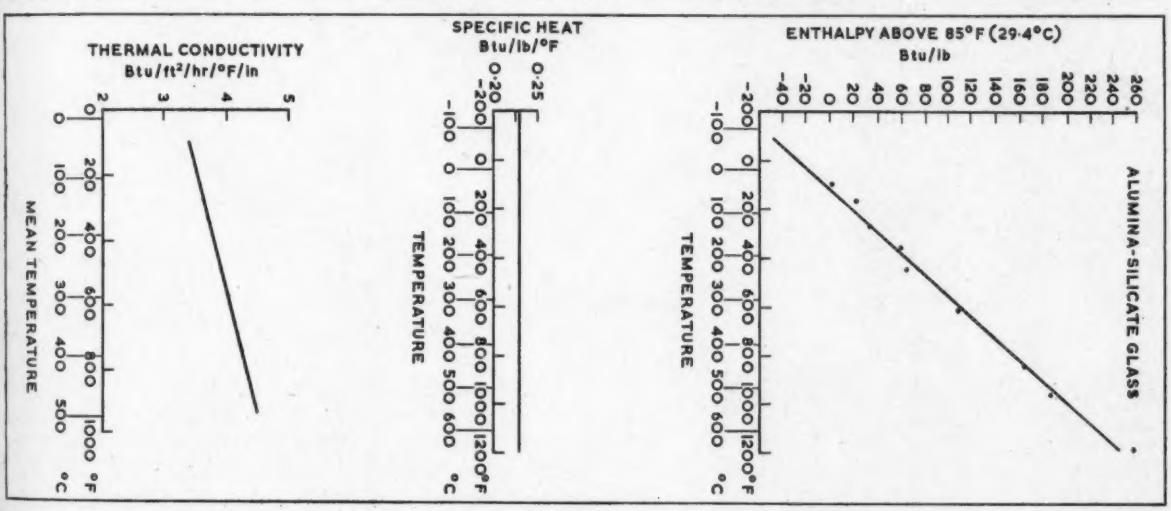
THERMAL PROPERTIES OF THREE GLASSES

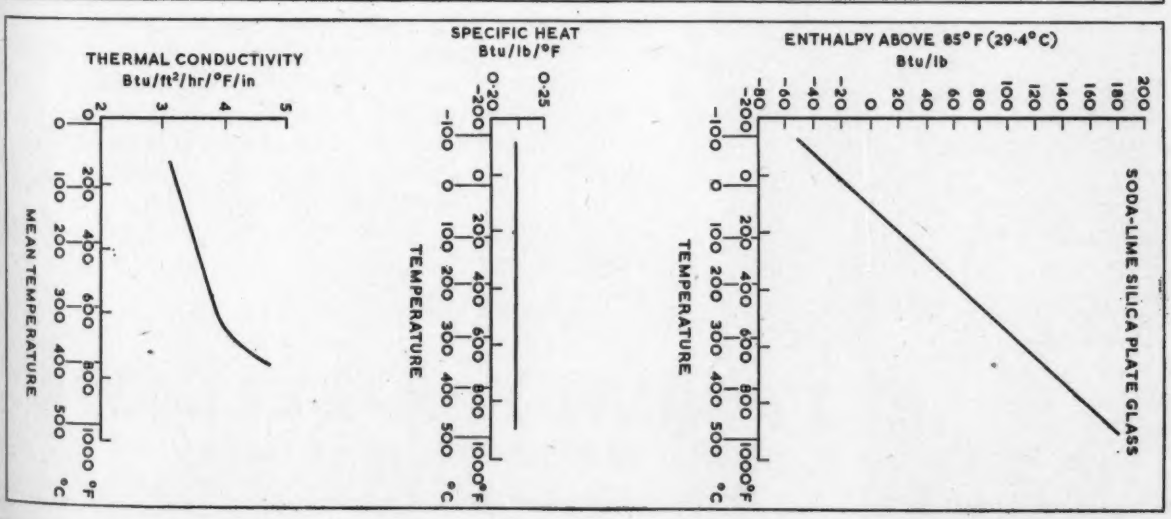
BORO-SILICATE; ALUMINA-SILICATE; SODA-LIME SILICA.

Engineering Materials and Design

DATA SHEET No. 34







Extracted from W.A.D.C. Report 58-129

EMD 2518 for further information

Expansion, contraction and lateral movement of pipe work under extreme conditions of temperature and pressure is no problem to the engineer who has been wise enough to contact and consult TEDDINGTON technicians. Teddington Bellows Expansion Joint cylinders are butt-welded from highly finished cold rolled stainless steel sheet. Convolutions are introduced to give the bellows their characteristic flexibility. Nuclear, chemical, marine and gas engineers acknowledge their efficiency and superiority over many older forms of expansion joint. Wherever pipe-work is subjected to vibration or movement in any direction, a Teddington Bellows with a suitable end-fitting will solve the problem.

SEND FOR BROCHURE No. X47

Made under licence from Solar Aircraft Co., U.S.A.

TEDDINGTON BELLOWS

EXPANSION JOINTS

TEDDINGTON AIRCRAFT CONTROLS LTD. (*Industrial Bellows Division*)
Ammanford, Carmarthenshire. Tel.: Ammanford 2255

FLYWHEEL ENERGY

Engineering Materials and Design
DATA SHEET No. 35

This nomogram gives solutions for flywheel energy or "driving power" available from a flywheel for press work, etc.

Scale A gives energy available corresponding to a nominal slow-down of 10 per cent (i.e., 10 per cent loss of flywheel r.p.m.) and is the maximum which can safely be extracted for continuous operation.

Scale B gives energy available consistent with a nominal slow-down of 20 per cent, which is the maximum normally advisable for intermittent operation.

Matching motor performance is also related to the operation involved. If the flywheel energy available is sufficient for the job, the motor has only to return the flywheel to speed, when a suggested formula for motor horse-power required is

$$\text{h.p.} = 0{\cdot}0054 \times E \times \text{cycles per minute}$$

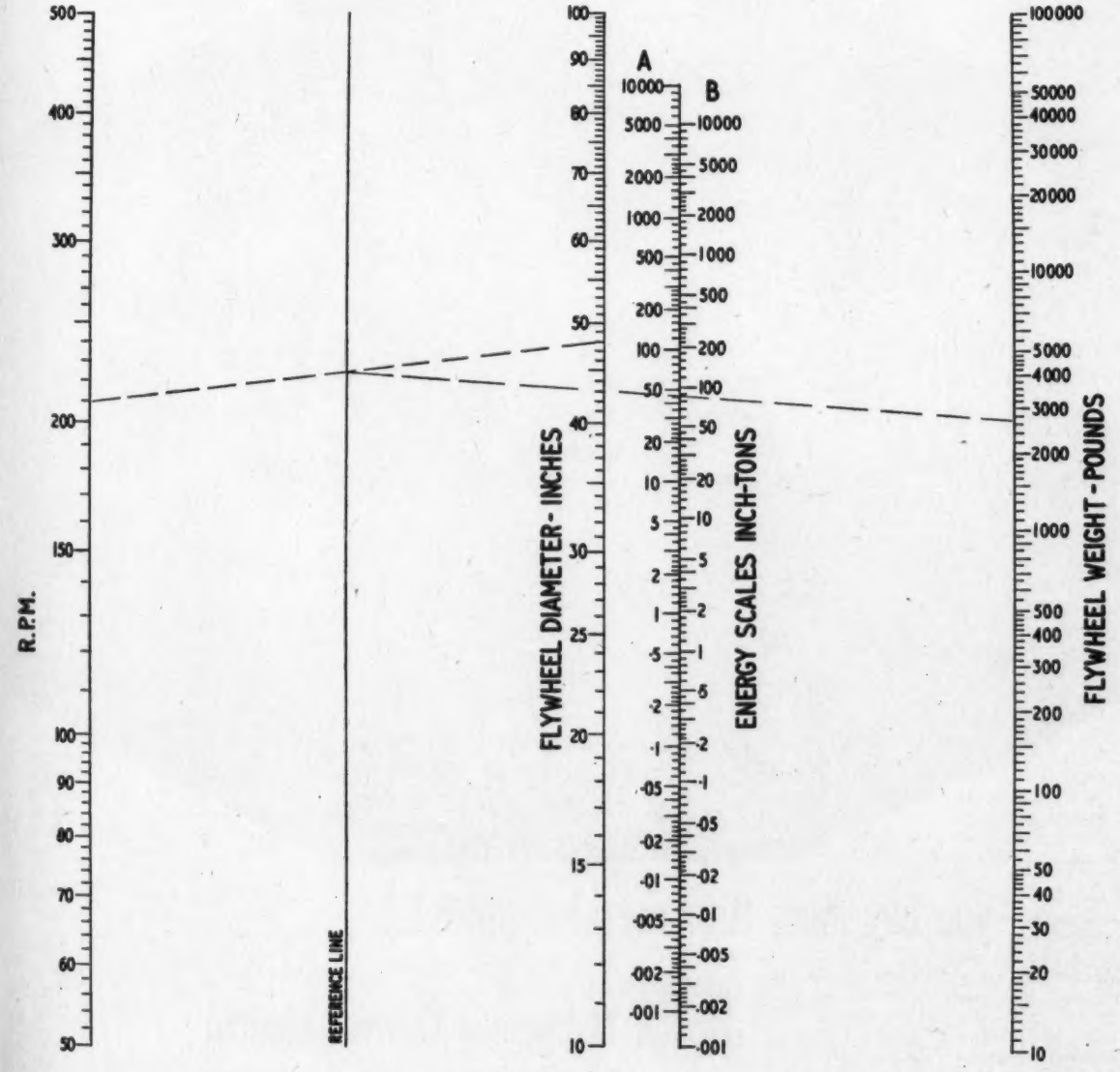
where E is the job energy requirement in inch-tons, with due allowance for frictional losses, etc.

Example: To find the flywheel energy available from a 4-ft.-diameter flywheel, weight 2,640 lb., with normal r.p.m. = 210.

1. Connect r.p.m. and diameter values on the nomogram.
2. From the point established on the reference scale, join to flywheel weight.
3. If the job requirement is for continuous operation, read energy value on Scale A.

Answer: 45 inch-tons.

For intermittent operation, the energy value would be read off scale B.



Data Sheet by R. H. Warring

EMD 2519 for further information

M.E.L make Magnesium —and History

Most things magnesium in this country—
from alloy to finished article—
owe much to the technical knowledge,
practical skill and manufacturing facilities
of the Company which pioneered and promoted
the metal in Britain; Magnesium Elektron Limited.
In fostering the idea of ultra-lightness,
and transforming it into an engineering fact,
M.E.L have won for magnesium a firm place
in the history of British industry.
They offer their unique experience, now as in the past,
to all metal-using industries where lightness,
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London Office: 5 Charles II St. St. James's SW1. Tel. TRAfalgar 1646
Magnesium Elektron, Inc., New York 20, USA

WHAT'S NEW IN MATERIALS & COMPONENTS

Machinable Ceramic

Ceramtec is a close-grained and uniformly-textured ceramic which is neutral and stable and provides an electrical resistor of high specific and surface resistance. It may be heat-treated in stages up to quartz hardness and, in this condition, is claimed to be an almost universal electrical, thermal and chemical insulator. Having all-round machinability and powers of insulation, it lends itself to applications in many fields, from minute radio components to heavy section crucibles. Current applications include high-frequency electrode carriers, miniature bobbins, connector blocks, element cores, turbine igniters and nozzles, corrosion-resistant bearings and for nuclear engineering components. It is claimed that parallel bores are readily obtained, and standard thread forms can be produced, without grinding, from B.A. sizes upwards. The Ceramic Development Co., 23 Kingston Road, London, S.W.19.

EMD 2602 for further information

Decorative Laminates

Texamel and Duralam melamine laminates enable steel, aluminium and plywood to be covered inexpensively with a decorative and highly resistant coating. Duralam is available in thicknesses between 0·017 and 0·028 in., the standard thickness being 0·020 in. Texamel is approximately 0·015 in. A great variety of adhesives can be employed, according to the base material to be used. For plywood and hardboard, resin and powdered glues, and those having a urea-formaldehyde base, can be used, as well as rubber-based adhesives. For steel and aluminium various rubber-based adhesives are recommended. F. Hills & Sons Ltd., Norton Road, Stockton-on-Tees.

EMD 2603 for further information

Low-carbon Lubricant

Electrolube is a complex low-carbon liquid composition which increases conductivity between conducting surfaces. It is claimed to be water-repellent, contains no mineral oil and retains its efficiency over a wide range of temperatures. It is claimed not to attack nylon, polythene or the formaldehydes. It is recommended for use in relays, terminals, electric motor brush gear, plugs and sockets, potentiometers, vibrators, fine coil suspensions, switches and any equipment with contacting surfaces. It is also said to penetrate oxide, sulphide and other chemical films without attacking the contact surfaces. Holliday & Hemmerdinger Ltd., 71 Ardwick Green North, Manchester, 12.

EMD 2604 for further information

Plating Stripper

Niplex A and B are two solutions used to make up a bath that removes nickel and cadmium without pitting or corroding the base metal, even where it is zinc or copper.

The solution is non-electrolytic and can be operated cold or heated up to 80 deg. C. The stripping rate of a fresh bath at room temperature is said to be approximately 0·00025 in. of nickel per hour. This can be accelerated by heating the solution to a maximum of 80 deg. C. and the stripping rate is then increased to 0·003 in. per hour, while in a special dilute bath at boiling temperature the stripping rate can be further increased to 0·0026-0·009 in. per hour.

Niplex solution contains no cyanide, caustic or acid, does not fume and is said to be stable for long periods. Roto-Finish Ltd., Mark Road, Hemel Hempstead, Herts.

EMD 2605 for further information

High-temperature Steels

The Jethete range of steels was initiated because of the limitations of existing steels in providing adequate mechanical strength at elevated temperatures combined with good corrosion resistance. They are low-carbon 12 per cent chromium-nickel steels and contain additions of molybdenum, vanadium, niobium and other elements as may be required to produce the desired properties. Jethete M.151 has a composition controlled so that the structure is fully austenitic at solution and welding temperatures, although the tempering resistance is not so great as to prevent softening prior to fabrication. Its major use is in sheet form, where it is capable of softening for fabrication by pressing, but the full mechanical properties are claimed to be recovered by simple heat treatment.

Jethete M.152 is a development from M.151, but with high-impact properties and a low transition temperature, an advantage when producing large sections. Jethete M.153 has an intermediate strength and has higher impact properties and a slightly lower cost than M.152. For properties in excess of the 400-500 deg. C. temperature range and particularly for use in aircraft turbines M.160 was developed. This is a 12 per cent Cr-Ni-Mo-V-Nb composition, the niobium addition providing the improved high-temperature strength. For still higher temperatures Jethete M.210 was developed, a 12 per cent Cr-Ni-Mo-Co-B composition, and further compositions are envisaged. United Steel Companies Ltd., 17 Westbourne Road, Sheffield.

EMD 2606 for further information

Stainless Filter

Porosint Rigimesh is a new stainless-steel filter material produced by sintering. It is claimed to embody the heat- and corrosion-resisting characteristics of stainless steel and is claimed to be tough, ductile and fracture-proof. Sintered Products Ltd., Sutton-in-Ashfield, Notts.

EMD 2607 for further information

Phenolic Resin Foams

Low-density cellular materials for use in thermal insulation and as lightweight core materials for sandwich panels can now be made in densities from 1-6 lb./cu. ft. To produce these, a resin, a hardener and a foaming agent for mixing together are supplied. The mixture is poured into a mould for making large blocks for cutting into slabs, or into cavities for foaming *in situ*. The complete process of mixing and foaming is said to take less than 10 min. The foams produced are stated to be inexpensive, self-extinguishing, heat-resistant, to have good thermal insulating properties, be unaffected by most solvents and be vermin-proof. They can be used for both hot and cold insulating applications. Bakelite Ltd., 12-18 Grosvenor Gardens, London, S.W.1.

EMD 2608 for further information

Dip-Coating Powders

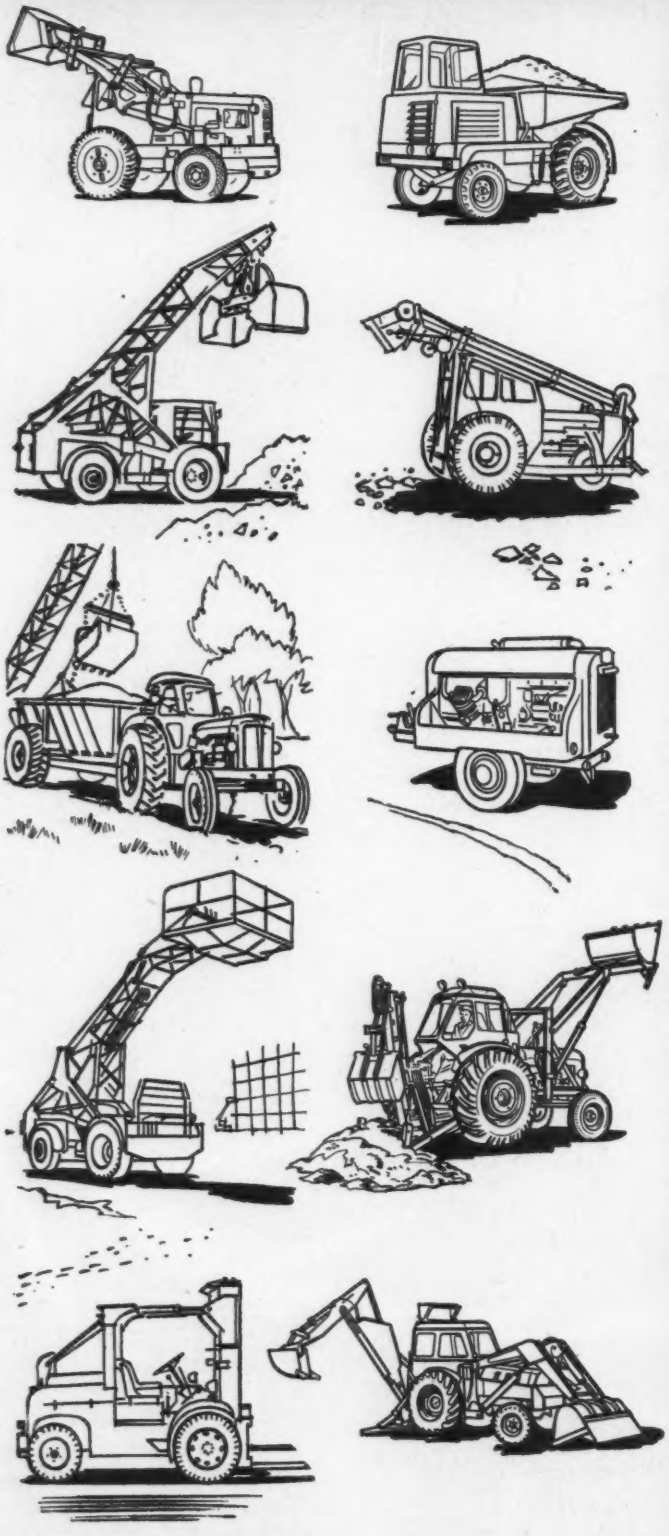
Telcon C.A.B. powder for dip-coating, in black, white and a number of attractive colours, is now available. It is specially recommended for work on which a hard-high-gloss finish with good impact strength is required. The coating is also claimed to be a good insulant and to resist attack by a variety of chemicals.

For the best results the manufacturers recommend that the powder be fluidised, a gentle air-flow through the fluidisation unit only being necessary. If the work-pieces are preheated sufficiently, enough heat is retained to fuse the coating completely after removal from the powder without the use of a second heating stage. A fine gloss on the coated articles is said to be obtained by quenching in water containing a detergent.

C.A.B. coatings, although said to be rather inferior to polythene in chemical resistance, is considerably superior mechanically. It is, however, said to be superior for use in contact with mineral oils. It has been successfully used for door handles, hand-wheels, plugs and sockets, switches, springs, refrigerator trays and for garden furniture. Telegraph Construction & Maintenance Co. Ltd., Mercury House, Theobalds Road, London, W.C.1.

EMD 2609 for further information

EXPERIENCED OPERATORS INSIST ON



FORDSON POWER

Men who have kept to the tightest schedules in the toughest conditions; men who have manned machines working round the clock, seven days a week; these are the men who know from experience that for proved reliability Fordson Power is unequalled. Add to reliability all the other Fordson advantages of high output, low costs, unrivalled service and spare parts organisation, and almost unlimited choice of build-ups in the 30-40 and 40-50 b.h.p. classes. That's why more Fordson power units than any other are used in industrial equipment. Write for detailed specifications.

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INDUSTRIAL SALES DEPARTMENT · TRACTOR DIVISION
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Adhesive Shading Film

Plastitone and Pretak shading patterns enable the production of engineering and other drawings to be speeded up. They are self-adhesive films, pre-printed with a variety of patterns from ordinary cross hatching to the effects required for brickwork, etc. Plastitone is a latex laminated film which is laid on the subject to be shaded and then cut with a sharp point. It can be scraped away with a sharp knife if required. It is said to be ideal for photographic use. Pretek is a wax laminated film which allows for delicate location and fine adjustment. Laid over the work and cut to shape, it will not adhere until it has been pressed down and well rubbed with the finger, bone or a special tool. Once rubbed down it adheres firmly. A. West & Partners Ltd., 36 Broadway, London, S.W.1.

EMD 2610 for further information

Solenoid-operated Valve

A solenoid-operated valve, for installation in liquid-carrying pipelines, has been developed to start or stop the flow of liquid in a pipeline by the establishment or failure of the electric supply current. The valve may be used as a remotely controlled stop valve. One important application of such a valve is its closure to keep a pipeline full of liquid in the event of current failure to the motor driving the pumps.

The valve is available for operation from d.c. or a.c. supplies, and both flameproof and non-flameproof versions are available. It is normally manufactured from high-tensile aluminium alloy, but it can also be supplied in forged steel. Simmonds Aerocessories Ltd., Treforest, Pontypridd, Glam.

EMD 2611 for further information

Pipe Thermocouples

These are designed for checking temperatures of piping of a wide variety of diameters. They can be used for either short-duration temperature tests in industrial plants or for permanent temperature indicating systems in office blocks, hospitals, etc.

In tests of short duration they are normally used in conjunction with a portable indicator, supplying a valuable aid to heating and ventilation engineers and inspectors. For permanent use, a number of pipe thermocouples are attached to pipe heating systems at intervals, and joined to a multipoint indicator.

The thermocouple is said to be suitable for measuring temperatures up to 300 deg. C. Cambridge Instrument Co. Ltd., 13 Grosvenor Place, London, S.W.1.

EMD 2612 for further information

Enclosed Motors

The development of totally-enclosed, fan-cooled, industrial a.c. motors with Class E insulation, said to develop up to twice the power of previous standard totally-enclosed machines of equivalent frame size, is announced. Rating for rating, these new motors, designated series 5 T.E.F.C., are said to be substantially smaller and lighter, and on the average 9½ per cent lower in cost than the machine they supersede.

Electrically they conform to B.S. 2613: 1957 Class E insulation. Dimensionally, they conform to a new B.S. draft specification and their fixing dimensions are the same as Series 5 ventilated motors to B.S. 2960: 1958.

The standard rotor is suitable for the majority of normal applications, but by variation of the rotor design it is possible to provide different starting characteristics to suit special requirements of driven machines. Crompton Parkinson Ltd., Crompton House, Aldwych, London, W.C.2.

EMD 2613 for further information

Self-priming Pump

The range of available centrifugal pumps has been increased by the addition of a new vertical self-priming unit, the VRL. 225. It is said to be robustly designed for general-purpose pumping duties and to be suitable for handling clear or cloudy liquids up to 150 deg. C., fuel and diesel oils and other oils up to 450 sec. Redwood No. 1, and also volatile liquids.

It is claimed that the VRL. 225 primes quickly, the suction lift amounting to as much as 28 ft. when pumping cold liquids. The capacities and heads available are 70 gal./hr. at 100 ft. of liquid and 400 gal./hr. at 25 ft. New features include a casing designed so that if the foot valve on the suction line should be inoperative the pump will continue to work, an impeller specially shaped and fitted with very short blades to prevent breakage on bending, and also fixed so that it is not in contact at any point with the casing and there is consequently no wear on the impeller. Precision Electrical Products (Stockport) Ltd., Lytham Street, Cale Green, Stockport.

EMD 2614 for further information

Digital Dial

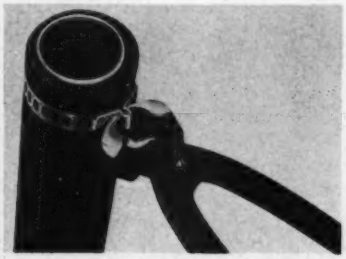
The Novotechnik digital dial is available in three-turn, ten-turn and fifteen-turn types. A brake is provided so as to avoid accidental upsetting of any preset value of rotation. The dials fit standard 0·25-in. shafts, but models for 6-mm.-type spindles are also available.

The dials are widely suited to many applications, e.g., potentiometers and thermostats, cam mechanisms and preselectors. For applications requiring remote setting of potentiometers, motor-driven types of the ten-turn pots are available. Kynmore Engineering Co. Ltd., 19 Buckingham Street, London, W.C.2.

EMD 2615 for further information

Speedy Hose Clip

A clip known as the O-clip for fitting on rubber, wire braided, p.v.c., polythene or canvas-covered hose is claimed to be one of the easiest and speediest of its kind



to attach. It is said that it can be fitted in a few seconds without any special tools other than a good pair of pincers. The clips are available in three ranges, standard, light and heavy from ¼ in. to 1$\frac{7}{8}$ in., and they are made from thermally-treated mild steel zinc plated. Matchless Machines Ltd., 13 Tottenham Court Road, London, W.1.

EMD 2616 for further information

Pressure Gauge

This multi-turn pressure gauge has been designed to cover a pressure range of 0-1,000 in. water. Indication is by means of a 6-in.-diameter dial which carries two pointers; figures are black on a white background and the scale graduation is 0-100 in. water per/rev. by a large pointer and 0-1,000 in. water, in steps of 100 in. water, by a small pointer on the inner scale. Luminous figurations are also available.

Temperature and barometric compensation over the complete scale range can be provided if required. The standard accuracy of this instrument is ±1 per cent F.S.D., but ±0·3 per cent can be met for special requirements. Appleby & Ireland Ltd., Basingstoke, Hants.

EMD 2617 for further information

Transistor Clip

A clip has been developed for fixing certain types of transistors horizontally to printed-circuit boards. The clip will suit cylindrical-shaped transistors of 6 mm. dia. and is said to take up no more room on the circuit board than the transistor itself. The clips are manufactured from beryllium copper to provide adequate heat dissipation. Lewis Spring Co. Ltd., Redditch.

EMD 2618 for further information

EMD 2521 for further information

In tubes...

ELMTUBE

HIGH FREQUENCY WELDED ALUMINIUM ALLOY TUBES

ELMTUBE means aluminium alloy strip to tube at 400 feet per minute, resulting in reduced production costs. ELMTUBE being mechanically rolled and formed, means straightness with roundness. ELMTUBE means consistent wall thickness, providing more feet per pound. ELMTUBE can be

formed, pierced, drilled, polished and anodised

Elm Engineering Limited

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a member of the Antiference Group

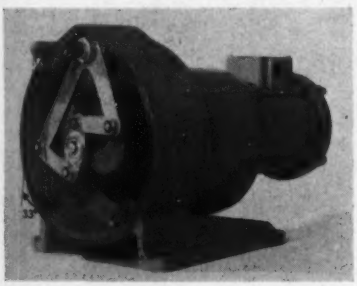
Pressure Transmitter

The Model 1465 differential pressure transmitter is the latest addition to the range of flowmetering instruments now available in the U.K. It is used to convert a differential pressure to a proportional pneumatic output signal of 3-15 p.s.i.g. for the operation of remote flow-rate indicators, recorders or controllers. The transmitter is a force-balance type with continuously adjustable damping, built-in over-range protection and it is temperature compensated. Its range is continuously adjustable from 0-20 in. to 0-200 in. water gauge, and the zero is externally accessible. The range can be further increased to accommodate from 0-30 to 0-300 in. water gauge with equal facilities for adjustment. Fischer & Porter Ltd., Salterbeck Trading Estate, Workington, Cumb.

EMD 2619 for further information

Reciprocating Drive

For jobs requiring a to-and-fro movement, a self-contained reciprocating drive unit with integrally mounted geared motor has recently been developed. The output shaft is centrally positioned over the motor axis in this compact, enclosed unit.



Developed from a classical linkage and lubricated for life, the unit can be supplied with reciprocation rates from 140 down to 0·08 cycles per minute. The angle of oscillation is 33 deg. maximum. Alternatively, it could be driven by a standard variable speed drive.

A torque of 50 lb./ft is available at rates of 26 c.p.m. and under. Above this speed the output is limited by the horse-power of the motor, which is ¼ h.p. Servotec Ltd., 265 Finchley Road, London, N.W.3.

EMD 2620 for further information

Shaft Speed Indicator

A photo-electric probe unit (type MA.51) has been designed to operate a frequency meter for the accurate measurement of shaft speed where it is impossible to make physical connection to the shaft under examination. It is necessary to make a mark on the shaft that will reflect light, and if the probe unit is held close to the shaft a pulse will be obtained each time a mark passes by. If a disc can be attached to the shaft with 60 marks on it and the output fed to a counter with a gating period of one second, then the speed will be indicated directly on revolutions per minute. Higher accuracies can be obtained by using a greater number of marks. The probe can also be used with an integrating-type frequency meter to provide a less expensive but less accurate speed indicator on a moving coil meter. The probe contains a germanium photo-transistor and an associated light source housed together in one unit. Racal Instruments Ltd., Bracknell, Berks.

EMD 2621 for further information

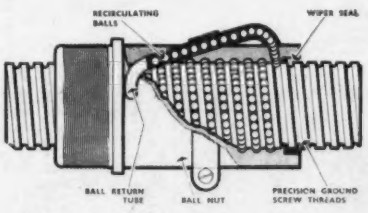
Vacuum Variable Capacitor

The special feature claimed for these components is their small size relative to their high voltage rating. This is made possible by the use of a vacuum dielectric which is said to enable capacitors to withstand breakdowns caused by temporary voltage overloads or transients without damage. Over the specified range the capacitance is said to vary linearly with the rotation of the operating shaft and precision construction is said to ensure a high degree of accuracy in the capacitance change produced by each turn. Capacity ranges are 5-30, 8-50, 10-80 and 15-200 pF., the maximum peak R.F. voltage being 15kV. for the first three types and 10 kV. for the last type. The movement of the capacitor takes place via a bellows, so that the unit is completely sealed, so enabling a very high vacuum to be retained. English Electric Valve Co. Ltd., Chelmsford, Essex.

EMD 2622 for further information

Ball Screws and Splines

One means of overcoming undesirable friction is by the use of rolling—as opposed to sliding—surface contact. This is the principle applied throughout a range of recirculating ball screws and splines now being marketed.

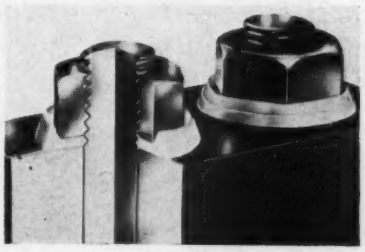


Ball screws (see diagram) are basically similar to ball-bearing races, except for the absence of the retainer. They are designed for the transfer of axial thrust, and so resemble angular contact bar bearings and, like the latter, the sides of the ball grooves in the screw extend almost to the mid-point of the ball. They are used in many fields where a torque must be converted to an axial thrust—or vice versa—and where efficient operation is essential, e.g., actuation mechanisms for landing gear and in control apparatus for numerous types of aircraft and guided missiles, machine tool, steam and sluice valve operation. They are capable of operating efficiently and for long periods without lubrication at temperatures as high as 400 deg. C. They are made with a lead accuracy of 0·0005 in. per ft. They can be made as small as 2 in. long × $\frac{1}{16}$ in. pitch diameter.

In the ball-bearing spline there are no teeth and keyway as in a conventional spline and the rolling balls in surface contact perform all the functions of normal splines with none of their drawbacks. Their efficiency is said to be about 40 per cent greater than that of the conventional type. Bristol Siddeley Engines Ltd., P.O. Box 3, Filton, Bristol.

EMD 2623 for further information

Bolt Locking Ring



The Dubo retaining ring is a retaining and lock washer of special design, manufactured from Akulon, a plastics material which undergoes modifications in form at high pressures, and possesses the additional advantage of pairing very low weight with great strength.

The special shape of the symmetrical ring shank, which is double T-shaped in section, is claimed as the reason for the retaining powers of the Dubo rings. In the first place, it has the locking action of a normal lock washer, and the elastic distortion, which occurs when the material is subjected to heavy pressures, results in the creation of considerable frictional resistance.

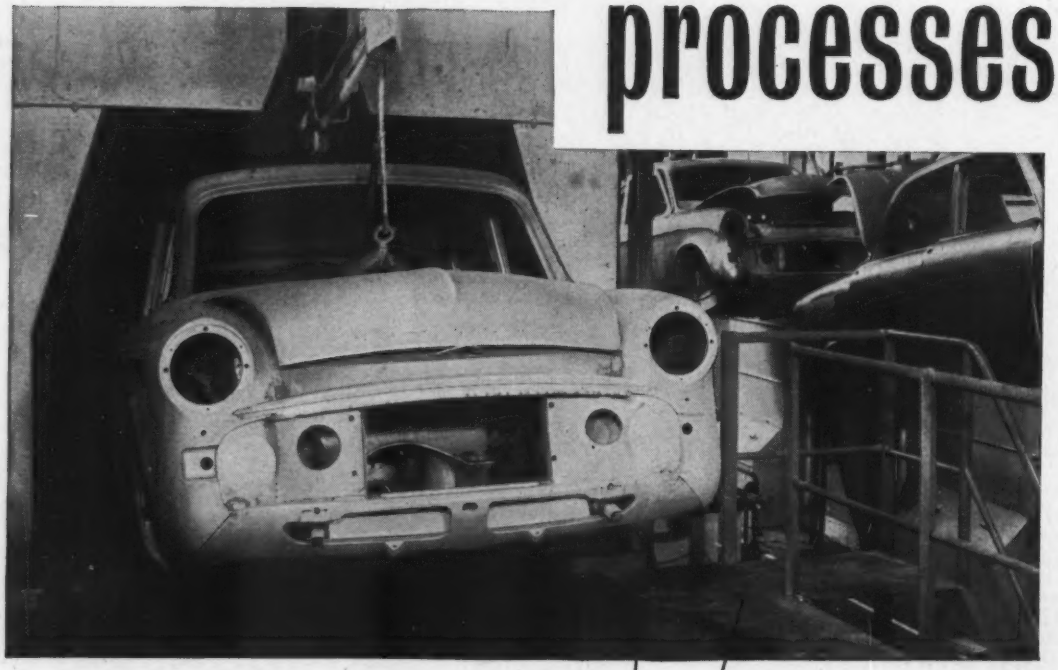
As soon as the bolt is screwed home, the bulge grips into the screw thread of the bolt, both along the internal circumference and in the bolthole. The plastics forced into the screw thread in this way brings additional frictional force into play, rendering it impossible for the ring to rotate around the bolt. In the same way, the outer bulge holds the nut in position.

As the material is also forced between the screw threads of the nut and bolt, further frictional resistance is created. Neither vibration nor shocks are said to have any effect on this double-locking action. Fan Disc Ltd., 109-111 Northwood Street, Birmingham, 3.

EMD 2624 for further information

EMD 2522 for further information

new BONDERITE processes



The sodium-free 'Spra-Bonderite' 115 process is one of the new treatments referred to in this advertisement and is in full production use at the Cowley Works of Pressed Steel Company Limited.

Get up to date with the latest Pyrene metal pre-treatments and finishes by telephoning us now or writing for further details to dept. E.M.D.4.

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cut production costs

BY REDUCING

* Chemical consumption
* Operating temperatures
* Plant maintenance

. . . producing REFINEMENT OF COATINGS where required

Photoprinting Machine

The Admel Revojute Meteor, which handles continuous lengths of materials as well as cut sheets, has undergone recent modifications and is claimed to incorporate many improvements. Printing speeds up to 30 ft./min. are possible, the printing and developing process being fully synchronised. Lawes Rabjohns Ltd., Abbey House, Victoria Street, London, S.W.1.

EMD 2625 for further information

Ultrasonic Cleaning

A new range of ultrasonic cleaning units has been designed for continuous operation for use by unskilled operators. This equipment is suitable for the majority of work where manual loading of parts is permitted using either aqueous solutions or solvents. The cleaning units for use with aqueous-based solutions are available with optional water-rinsing facilities and continuous fine filtration. Those for use with chlorinated solvents such as trichloroethylene or perchloroethylene are available with optional solvent redistillation recovery and vapour drying and multiple fine filtration. The units are designed for operation at any of the normal frequencies used for ultrasonic cleaning, i.e., 20 kc/s, 40 kc/s or 1 mc/s. Kerry's (Ultrasonics) Ltd., Warton Road, London, E.15.

EMD 2626 for further information

Bench Muffle Furnace

A new bench-model muffle furnace has been developed as a compact unit for temperatures up to 1,000 deg. C. The working chamber consists of a Nichrome-wound muffle forming an independent unit readily interchangeable with the minimum of effort. The muffle size which has proved to be most practicable for test firing samples is 18 in. deep × 5¼ in. high × 7¼ in. wide. The furnace operates off standard single-phase supplies, is normally rated at 2·75 at 230 volts and reaches 800 deg. C. in two hours. Temperature uniformity is within 5 deg. from the front to the rear of the muffle, and temperatures are said to be extremely stable. Ferro Enamels Ltd. (Allied Engineering Division), Wombourn, Wolverhampton.

EMD 2627 for further information

Welding Rectifier

A new portable d.c. power unit, the PR.250 "plug-in" rectifier, has been introduced. It is designed as an inexpensive and convenient means of obtaining d.c. welding current directly from existing a.c. equipment. While a.c. supply is commonly used for most arc welding applications, d.c. is needed for the deposition of certain special electrodes, particularly non-ferrous types. The "plug-in" rectifier therefore enables both ferrous and non-ferrous electrodes to be deposited with the minimum additional outlay. It may also be used as a power source for the argonarc welding process, provided that H.F. filters are fitted. The PR.250 can be used in conjunction with most conventional single-operator a.c. welding sets of 300 amp. maximum output and an open circuit voltage range of 80-100 volts.

The rectifier is a simple, compact unit housed in a weatherproof sheet-steel case and mounted on skids. It consists of a naturally air-cooled rectifier bank bridge-connected for full wave rectification and with a smoothing choke to give good arc stability. The silicon rectifier elements are completely sealed from the atmosphere and will not deteriorate in service.

Welding current follows closely that of the a.c. input and is adjusted from the control of the associated a.c. set. The open circuit voltage is approximately 70-85 volts, depending on the open circuit voltage of the a.c. transformer, and a maximum d.c. current of 250 amp. can be obtained. No cooling fan is needed, there are no moving parts and connection is made by "plugging in" the two rectifier leads to the output terminals of the a.c. welding set. Quasi-Arc Ltd., 213 Oxford Street, Bilston, Staffs.

EMD 2628 for further information

Illuminated Magnifier

An unusual illuminated magnifier specially designed for use in examining and also working on maps, charts, engravings, textiles and printed matter of all kinds has just been put on the market.

The magnifier, the M.109, consists of a spun aluminium body 8 in. diameter × 6 in. high, which has fitted in the top a 5-in.-diameter optically-correct lens

which gives an area magnification of 4×. The design of the lens gives true binocular viewing without distortion over the whole area covered and without eye strain when used continuously.

Lighting comes from an 18-watt, 25-volt lamp fed from the main through a Dohm safety transformer plug which plugs directly into a standard three-pin mains outlet (three models are available: three-pin 5-amp., 15-amp. and 13-amp. flat). P. W. Allen & Co., 253 Liverpool Road, London, N.1.

EMD 2629 for further information

Heavy-duty Grease Pump

The Hercules high-pressure pump is specially suitable for feeding heavy lubricants at high pressures. It is capable of pumping bitumastic materials, and can operate at a maximum working pressure of 15,000 p.s.i. The pump is foot-operated; it has a handwheel which is turned down approximately every 20-40 applications to ensure that the lubricant finds its way into the pressure chamber.

The output per stroke may vary slightly with the type of grease; in the case of a grease of penetration 250 it is 2·3 grams per stroke. The high pressure that can be developed by the pump is said to be suitable for lubrication of chassis and machine parts and through long pipelines. It can also be used with positive dividers, and as such is an intermediate step between a centralised lubrication system and grease nipples. By inclusion of relief or other suitable valves, the Hercules can be adapted to operate with single-line and dual-line centralised lubrication systems. The weight of the pump is just under 50 lb., and it is equipped with two wheels for easy movement from one application area to another. Centralube Ltd., Eley Estate, London, N.18.

EMD 2630 for further information

Dry Duplicating

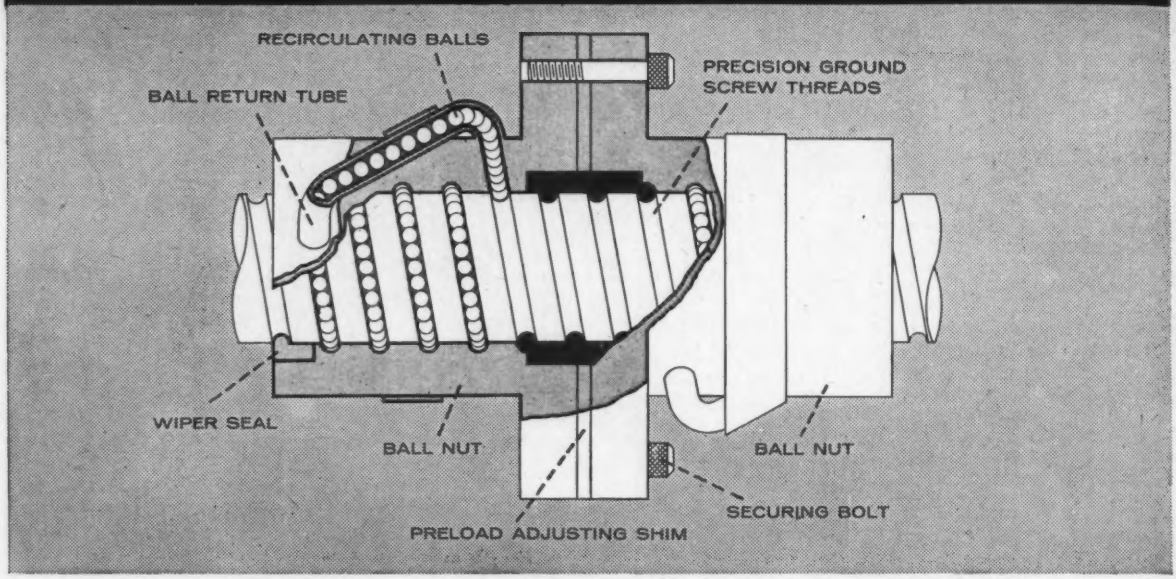
A unique and exclusive method of obtaining copies without stencils, ink, spirit or liquid of any kind is used by a new rotary duplicator, the Merlin. Copies are reproduced by means of a chemical reaction in the sensitised copy paper used.

The special master set has been designed to ensure cleanliness in handling, and hand or typewritten masters are easily prepared. There is said to be a complete lack of smell and mess, and the attachment and removal of masters is quick and easy. Another advantage with this method is that the machine is always ready for immediate use, as there is no damping or inking.

The duplicator measures 12 × 12 in., excluding driving handle, and the machine is light (20 lb.) and portable. Ellams Duplicator Co. Ltd., 5 Dean Street, London, W.1.

EMD 2631 for further information

Beaver pre-loaded ball screws, up to 95% efficient, operate at -52°C to over 400°C with no backlash...



...ANOTHER ENGINEERING ADVANCE FROM BRISTOL SIDDELEY

Bristol Siddeley Engines Limited produce Beaver* pre-loaded ball screws. These ball screws achieve a minimum efficiency of 90% and they can operate within a temperature range of −52° C to 400° C without lubrication, and up to 170° C when lubricated.

Machined and ground to the highest standards of precision engineering Beaver pre-loaded ball screws greatly increase transmission efficiency. They reduce the power required for actuation by as much as 80%, when converting rotary drive into linear output or force input into torque output. By eliminating backlash, with pre-loading, they give precise control over very small increments of motion and a high response frequency. And when compared to conventional screw mechanisms, they provide a predictable operating life which is much longer, require much less maintenance and give more trouble-free operation.

Basic design application analysis

Bristol Siddeley engineers make an exhaustive analysis of each specification. And each unit is specially designed for its particular application. Beaver ball screws are made automatically reversible or with controlled "no-back," with multiple or single circuits. Beaver pre-loaded ball screws have been proved as the most efficient method of converting rotary into linear thrust in over 2,700 engineering applications in many branches of industry. They have been designed already with rated operating load capacities of 370,000 lb (825,000 lb maximum static load) but the maximum potential operating load is, in most cases, limited only by the requirement.

Bristol Siddeley Beaver ball splines have been developed to eliminate the disadvantages of conventional splines. The designs are very effective in minimising friction, particularly when high torsional and bending loads are imposed during linear movement.

** Complete technical and manufacturing co-operation with Beaver Precision Products Inc., Detroit.*

For further information please write to J. B. Starky, Sales Manager (Beaver Products Division), Bristol Siddeley Engines Limited, PO Box 17, Coventry, England.

BRISTOL SIDDELEY ENGINES LIMITED

News of Industry

The Shell Chemical Co. Ltd. are offering prizes worth £1,000 in a plastics design competition. Awards will be made for an article or appliance for the industrial. domestic, institutional or public services market which could, with advantage, be made wholly from or incorporating a major proportion of either Shell polypropylene or high-density polythene. Closing date for entries is June 30. First prize is £500, second £300 and third £200. Judges will be Mr. L. H. Williams, managing director of Shell Chemical Co.; Mr. V. N. Kuke, Shell plastics division manager; Mr. Paul Reilly, director of Council of Industrial Design, and designer Mr. Robin Day.

The **Electrochemical Society** of the U.S.A. is sponsoring an international conference on the direct reduction process of iron production. It will be held in Chicago from May 2-5; twenty-one papers are scheduled which will review progress made in Canada, the U.S.A., the U.K., Sweden, France, Germany and Norway. Details are available in the U.K. through the British Iron and Steel Research Association, 11 Park Lane, London, W.1.

A series of specialist courses in liquid oxygen breathing systems for aircraft has been introduced by **British Oxygen Aviation Services** at Harlow. Classroom studies are supported by practical demonstrations in the laboratories and production shops.

A two-day appreciation course on ergonomics was recently held at the **Central College of Further Education**, Wirral, Cheshire. The course covered the broad aspects of adapting working equipment, space environments and consumer products for human use.

Firth Cleveland Steel Strip Ltd. have announced they are now specialising in the production of high carbon steel strip to the exclusion of all other cold-rolled products. The strip is offered in an extensive range of sizes, including widths from ¼ in. to 12 in. and thicknesses from 0·004-0·092 in. in coils or cut lengths.

The Central London Productivity Council has established a new Industrial Training Council concerned with the problem of training scientists, engineers and management for industry. A meeting on the subject is to be held on March 24 at the F.B.I. in London.

The **International Nickel Co.** of Canada has taken delivery of a regenerative gas-turbine engine to be installed in a truck for hauling ore at the company's open pit mine in Sudbury, Ont. It is the first time a gas-turbine engine has been subjected to the task of ore hauling. The engine is a GMT-305 Whirlfire, made by the Allison division of General Motors.

A branch of **Martins Bank Ltd.** has successfully experimented with a complete electronic computer programme capable of carrying out the whole of the current account book-keeping operation, including the production of statements of accounts for customers. The equipment is a Ferranti Pegasus II computer.

Prices of most auxiliary relays were reduced by **English Electric Co.** on March 1. The reduction, an average of 10 per cent, is attributed to the use of moulded plastics instead of pressed steel cases.

First awards in the plan for exchanging technical college teachers with the U.S.A. have been announced by the **English Speaking Union.** Four senior technical teachers—from Loughborough College of Technology, Swansea Technical College, Brighton Technical College and Brunel College of Technology—are to spend eight weeks in the U.S.A. Objects of the scheme are to enable those selected to understand one another's technical background and working and living conditions.

A conference on non-destructive testing in electrical engineering is to be held in London at the **I.E.E.** from November 8-10 next year. It is being planned in association with the British National Committee on Non-Destructive Testing.

An exhibition is to be held in London this autumn devoted to all aspects of electrical equipment for the home. The public will be admitted during the entire exhibition, which will take place at Alexandra Palace from September 23 to October 1. One of its objects will be to show the public how to select and use safe equipment.

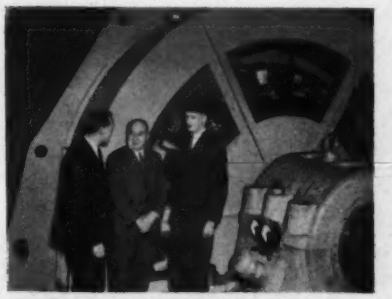
A new research reactor of the **U.K.A.E.A.** has started operation at Aldermaston. Known as the "Herald", it will be used for nuclear research work requiring intense neutron beams and for irradiation-damage studies on reactor materials. It is a light water-moderated and -cooled tank-type thermal reactor designed to operate at 5 MW. continuously. Its core is in the form of thin plates of enriched uranium-aluminium alloy suitably spaced in water.

Durable Plastics Ltd. have announced a change of name of their company, as from April 1. The organisation is now to be known as Plastic Coatings Ltd. Management and other personnel are not being affected by this alteration.

A new company, **Drayton-Southern Ltd.**, is being formed jointly by Southern Instruments Ltd. and the Drayton Regulator & Instrument Co. Ltd. "for the purpose of expanding the instrumentation and control interests of both companies, whose research, production and sales resources will be available to it".

The Italian **RIV** company, part of the Fiat organisation, are offering £9,000 in an international competition aimed at promoting the study of plastics for structural and decorative use in architecture and industry. Closing date is April 15.

Bruno-Cape SA is the name of a company formed by Cape Asbestos Co. in conjunction with Bruno y Cia Com E Ind SRL of Buenos Aires and with the Johns-Manville International Corp. of U.S.A. The new company will manufacture compressed asbestos fibre jointings and other asbestos goods at Buenos Aires.



Motors for the first twin-drive hot reversing mill in Britain with the main-drive motors supplied from mercury arc converters are now undergoing tests at English Electric before delivery to Consett Iron Co. Here Mr. D. S. Apps, English Electric (left), discusses the project with Mr. T. Coxon, Int. Construction Co. (right).

Largest rolling mill of its type in western Europe has been ordered by **James Booth Aluminium Ltd.** as part of its expansion programme. The mechanical side of the new plant has been ordered from Loewy Engineering Co., and is designed to roll aluminium and Duralumin slab ingots weighing up to 6 tons.

A.E.I. radio and electronic components division have created a new product department devoted to semi-conductors for industrial and commercial applications.

F'AG Bearing Co. Ltd. have opened a new branch office at 86 Bristol Street, Birmingham, 5 (Tel. Midland 9209). Another branch has opened at 69 Temple Street, Wolverhampton (Tel. 20386).

Telemechanics Ltd. have moved to new premises at Brokenford Lane, Totton, Southampton (Tel. Totton, S'ton, 3666).

Simmons & Hawker Ltd. have moved to new offices and factory at Central Way, North Feltham Trading Estate.

EMD 2524 for further information

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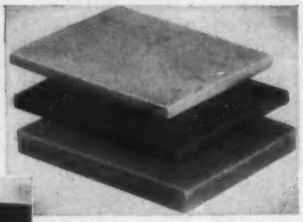

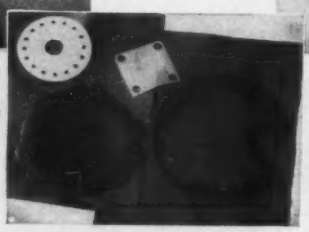

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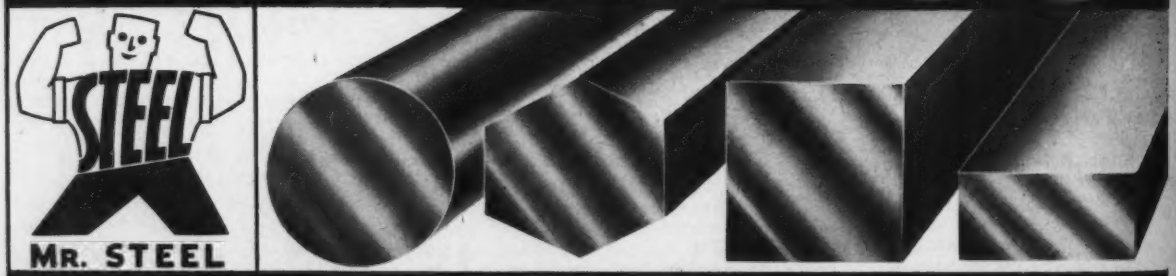

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EMD 2525 for further information